AD A118690

SYSTEM ENGINEERING ANALYSIS OF FEED AND CONDENSATE SYSTEM INSTALLED ON LHA-1 AND LPH-2 CLASS SHIPS

July 1982

Prepared for
PLANNING AND ENGINEERING FOR REPAIRS AND ALTERATIONS
AMPHIBIOUS SHIPS AND CRAFT
PORTSMOUTH, VIRGINIA
under Contract N00189-81-D-0126-FJ07

ARINC RESEARCH CORPORATION

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER 2657-01-3-2754	2. GOVT ACCESSION NO. AD-A118690	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) System engineering analysis of feed and condensate system installed on LHA-1 and LPH-2 class ships.		5. TYPE OF REPORT & PERIOD COVERED
		6. PERFORMING ORG. REPORT NUMBER 2657-01-3-2754
7. AUTHOR(s) R. M. Evans		8. CONTRACT OR GRANT NUMBER(s) N00189-81-D-0126-FJ07
9. PERFORMING ORGANIZATION NAME AND ADDRESS ARINC Research Corp. 2551 Riva Road Annapolis, Md. 21401		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS Planning and Engineering for Repairs and Alterations Amphibious Ships and Craft, Portsmouth, Virginia.		12. REPORT DATE July 1982
		13. NUMBER OF PAGES 87
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Unlimited

DISTRIBUTION STATEMENT A

Approved for public release; Distribution Unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

System Engineering Analysis
Shipboard Feed Systems
Shipboard Condensate Systems
LHA-1 Class Ships
LPH-2 Class Ships

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The analysis contained in this report is specifically applicable to the Feed and Condensate Systme -- ship's work authorization boundary (SWAB) group 255 -- installed on LHA-1 and LPH-2 Class shops. The analysis considers only the systems and equipments installed and the documentation effective as of 22 April 1981. This system was selected for analysis by PERA (ASC) on the basis of its mission criticality and historical maintenance burden.

11

SYSTEM ENGINEERING ANALYSIS OF FEED AND CONDENSATE SYSTEM INSTALLED ON LHA-1 AND LPH-2 CLASS SHIPS

July 1982

Prepared for

Planning and Engineering for Repairs and Alterations
Amphibious Ships and Craft
Portsmouth, Virginia

under Contract N00189-81-D-0126-FJ07

by

R. M. Evans

ARINC Research Corporation
a Subsidiary of Aeronautical Radio, Inc.
2551 Riva Road
Annapolis, Maryland 21401

Publication 2657-01-3-2754

Accession For		
NTIS GRA&I		☒
DTIC TAB		☐
Unannounced		☐
Justification 1473 attached		
By		
Distribution/		
Availability Codes		
Dist	Avail and/or Special	
A		

SUMMARY

The goal of an engineered operating cycle (EOC) program is to effect an early improvement in the material condition of ships at an acceptable cost, while maintaining or increasing their operational availability during an extended operating cycle. In support of this goal, system engineering analyses (SEAs) are being conducted for various ship classes on selected mission-critical systems and subsystems that have historically exhibited relatively high maintenance burdens. This report documents the SEA for the Feed and Condensate Systems on LHA-1 and LPH-2 Class ships. The report was developed for PERA (ASC) under Delivery Order FJ07 of Navy Contract N00189-81-D-0126.

The SEA is an analysis of the impact of historical preventive and corrective maintenance requirements that affect operational performance and maintenance programs of a ship system and the significance of these requirements to an EOC program. The report documents a recommended system maintenance strategy and specific maintenance actions best suited to meeting EOC goals.

The major findings and conclusions of the SEA for LHA-1 and LPH-2 Feed and Condensate Systems are summarized as follows:

- The maintenance and failure history, redundancy, and criticality of the main feed pumps, emergency feed pumps, and main condensate pumps do not justify routine class B overhauls at five-year intervals. Given a satisfactory-quality overhaul and planned improvements, with proper maintenance during the operating cycle, the feed and condensate pumps should operate successfully with only occasional repairs for a 10-year period before requiring restoration to design specifications.
- An "on condition" maintenance strategy employing the assessment of material condition and operating performance as the basis for determining needed repairs is considered the most appropriate for the feed and condensate system in terms of cost and system operational availability. Cost (man-day) savings through reduction of depot-level routine overhauls should be realized through adoption of such a strategy.

- Significant improvements can be made to system material condition and the operational availability of system components if improvements are made in the areas of manpower, personnel, and training. Supply support is another area where improvements can result in significant increases in system material condition and operational availability.
- The operational availability of main feed booster pumps may be improved, maintenance burden reduced, and life-cycle maintenance costs reduced by replacing feed booster pump turbine drivers installed on some LPH-2 Class ships with electric motor drivers.
- Improved operational availability of main feed pumps installed on LPH-9 should be attained if existing pumps are replaced with new main feed pumps. This replacement may also be more cost-effective than a class B overhaul of the existing pumps.
- PMS, with some improvements, is generally adequate. Design and support improvements proposed by the DART Program should generally improve material condition and operational readiness, with perhaps the possible exception of Shipalt LPH-496K. This shipalt should be reevaluated to determine whether it can be cost-effective.

CONTENTS

CONTENTS (continued)

CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND

System engineering analyses (SEAs) are being conducted on selected systems and subsystems of designated ships of the Amphibious Force in support of an engineered operating cycle (EOC) program. The SEA is an analysis of the impact of historical preventive and corrective maintenance requirements that affect the operational performance and maintenance programs of a ship system. It serves as a vehicle for assessing the significance of these maintenance requirements to an EOC program. The objective of a SEA is to define and document a maintenance program that will prevent or minimize the need for unscheduled maintenance, while improving material condition and maintaining or increasing system availability throughout an engineered operating cycle.

1.2 SCOPE

The analysis documented herein is specifically applicable to the Feed and Condensate System -- ship's work authorization boundary (SWAB) group 255 -- installed on LHA-1 and LPH-2 Class ships. The analysis considers only the systems and equipments installed and the documentation effective as of 22 April 1981. This system was selected for analysis by PERA (ASC) on the basis of its mission criticality and historical maintenance burden.

The analysis used all available documented data sources from which system maintenance requirements could be identified and studied. These included the maintenance data system (MDS), casualty reports (CASREPs), planned maintenance system (PMS) requirements, ship alteration and repair packages (SARPs), system alteration information, system technical manuals, ship corrosion-control manuals, ship corrosion-control manuals, and Engineered Operating Cycle (EOC) system maintenance analyses (SMAs) previously conducted for functionally similar systems and equipments installed on EOC program ships. Sources of undocumented data used in this analysis included discussions with ships' operating personnel and cognizant Navy technical personnel.

1.3 REPORT FORMAT

The following chapters describe the analysis approach (Chapter Two), present the significant system maintenance experience and essential maintenance requirements (Chapter Three), and summarize the conclusions and recommendations derived from the analysis (Chapter Four). Appendix A defines the system boundaries used in conducting this analysis, and Appendix B lists the specific components that constitute the feed and condensate system as installed on individual ships of the ship classes under study. Appendix C provides IMA repair times for specific tasks appropriate to the feed and condensate system components. Appendix D is a summary of CASREPs reported. Appendix E specifies the Maintenance Index Pages (MIPs) applicable to the major components of the system. Appendix F presents recommended corrosion-control work items. Appendix G is a summary of applicable shipalts. Appendix H lists all sources of information used in this analysis.

CHAPTER TWO

APPROACH

2.1 OVERVIEW

This chapter describes the approach followed in performing the SEA for the Feed and Condensate System installed on LHA-1 and LPH-2 Class ships. The systems were selected for analysis by PERA (ASC) on the basis of its mission criticality and historical maintenance burden. Data from sources mentioned in Section 1.2 were used to identify, define, and analyze maintenance requirements that will significantly affect the system's operational availability and material condition. A recommended maintenance strategy and implementation procedures were formulated on the basis of the analysis results. The major steps of the analysis were as follows:

- Task 1: Compile data and prepare maintenance history profile
- Task 2: Analyze problems and causes
- Task 3: Analyze solutions to problems
- Task 4: Document SEA results

The following sections briefly describe each of the major tasks.

2.2 TASK 1: COMPILE DATA AND PREPARE MAINTENANCE HISTORY PROFILE

During Task 1, the configuration, boundaries, and functions of the system were defined; maintenance, engineering, and operating data were collected; and the maintenance history profile was prepared, describing the corrective maintenance historically performed. These items provided basic reference data for the remaining SEA tasks.

2.2.1 Collect Data

The analysis began with the collection of data on the historical maintenance requirements of each system. The resulting data file consisted of four key elements: an MDS data bank, a CASREP narrative summary, a current equipment configuration summary, and a summary of historical maintenance requirements. A library was also assembled from appropriate technical manuals, PMS requirements, SARPs, and copies of previously completed analyses of functionally similar equipments installed on EOC program ships.

The MDS data bank was compiled by examining all MDS data reported from May 1976 through June 1981 for Hulls LHA-1 through LHA-5, and 1 January 1971 through March 1981 for Hulls LPH-2, LPH-3, LPH-7, LPH-9, LPH-10, LPH-11, and LPH-12 (a total of 12 ships).

CASREP information was obtained by reviewing the CASREPs reported on each ship's system during the period of 1 January 1976 through 22 April 1981 for LHA-1 Class ships and 1 January 1978 through 22 April 1981 for LPH-2 Class ships. CASREPs resulting from parts cannibalization of equipments by other ships were not considered.

2.2.2 Define System Configuration

Configuration information was obtained by reviewing available common configuration class lists (CCCLs), the type commander's coordinated shipboard allowance lists (COSALs), shipalt records, and MDS data. Telephone calls to specific ships and cognizant technical personnel, as necessary, confirmed system configuration.

2.2.3 Prepare Maintenance History Profile

The maintenance history profile was prepared from analysis of MDS and CASREP data and review of applicable PMS documentation and SARPs. The maintenance history profile is a working technical package describing the types of corrective and restorative maintenance historically performed on the system, the level of maintenance typically required to perform the work, an estimate of the man-hours required, and the approximate intervals at which these maintenance actions can be anticipated.

2.3 TASK 2: ANALYZE PROBLEMS AND CAUSES

In Task 2 the data summarized on the maintenance history profile forms were analyzed, together with the available engineering data, to identify maintenance, support, and design problems and their associated causes. The problems and their causes were confirmed and data related to additional problems were uncovered through discussion with ships' forces and Navy technical personnel when possible.

2.3.1 Analyze Data to Define Problems

Recurring maintenance requirements affecting the availability and material condition of the equipments constituting the system were identified by screening the maintenance history profiles developed in Task 1. Screening of the maintenance history profiles had two major objectives:

- Identification of recurring failure modes or problems that require IMA, depot, or other off-ship assistance for correction and are common to all engineering designs of the functionally similar equipments installed on the ship classes examined.
- Identification of recurring failure modes or problems that are

either unique to or primarily associated with a particular equipment engineering design installed on a limited number of hulls.

Once the problems were identified, the previously completed EOC program SMAs for functionally similar equipments were reviewed to determine whether the same or similar problems had been previously identified on other ship classes. If such was the case, the need for additional detailed analysis was minimized.

2.3.2 Define Causes

Although it is presented as a separate subtask, the definition of problem causes was a continuing process that occurred concurrently with the definition of the problems. Concurrent effort was required for the following reasons:

- Problem causes were sometimes stated in the historical maintenance data.
- Causes or possible causes of problems were identified during discussions with Navy technical personnel or ships' forces.
- Problem causes had previously been identified by analysis of identical or functionally similar systems installed on other ship classes.

In general, the causes were grouped into three categories: maintenance strategy, design, and support.

2.3.3 Summarize Problems and Causes

The problems identified and the causes defined in Task 2 were summarized and carried forward to Task 3 for development of specific solutions. The summary descriptions included the following data:

- A statement of the problem and the most probable cause
- A summary of the pertinent maintenance history and engineering data, including man-hours, number of actions, and level of repair
- Other information affecting the problem, such as redesign work in process, applicable alterations, or the effects of maintenance availabilities

2.4 TASK 3: ANALYZE SOLUTIONS TO PROBLEMS

In Task 3 the problems identified in Task 2 were analyzed so that a recommendation could be made regarding a maintenance strategy, a support strategy, design changes for the associated equipments, or equipment that should be replaced.

2.4.1 Analyze Existing Solutions

The analysis of existing design solutions that might be applicable to the two ship classes under study had two basic objectives. The first was to determine whether the problem was known to the Navy technical community and whether or not a solution had been proposed or defined. To do so, currently authorized shipalts affecting the system or equipment under study were reviewed and, if necessary, interviews were conducted with Navy technical personnel. Where possible, the effectiveness of installed shipalts was assessed.

The second objective was to determine if the specific problem existed in other ship classes and, if it did, whether a solution had been defined and whether it was applicable to the problem associated with the ship classes under study. To meet this objective, previously completed analyses of functionally similar equipments installed on other ship classes were reviewed, and the various problems found were evaluated for similarity. If the problems were determined to be similar to those identified in this analysis, the previously developed solutions were assessed for applicability to the particular equipments installed on the ships under study. If found to be applicable, they were adopted and documented as recommendations in this report without further detailed analysis.

2.4.2 Analyze Potential Maintenance Strategies

Previously developed maintenance strategies for functionally similar equipments installed on other ship classes were reviewed for their applicability to equipment installations on the ships under study. If shown to be applicable by this analysis, they were adopted and recommended for implementation on these classes of ship.

Where previously identified maintenance strategies did not apply to the ship classes under study, maintenance strategies that could possibly apply were analyzed by using reliability-centered maintenance (RCM) logic. This approach used the information developed during previous tasks to answer a series of simple yes-no questions, which led to specific decisions concerning the suitability of scheduling maintenance tasks. Three types of maintenance tasks could result from the decision process:

- On-condition task - Inspect equipment operation to detect either experienced or impending failures
- Scheduled rework task - Rework an item before an established maximum age or operating interval is exceeded
- Scheduled discard task - Discard an item before an established maximum age or operating interval is exceeded

The results of this process led to the development of the maintenance strategies recommended for the systems and equipments under study for which previously developed maintenance strategies were inadequate.

2.4.3 Analyze Potential Solutions to Integrated Logistics Support (ILS) Problems

Analysis of possible improvements to the ILS of the systems and equipments under study was limited to only those systems or equipments having maintenance history profiles that indicated the presence of such problems. Such problems are typically identified during review of MDS or CASREP data. Excessive downtime awaiting parts and the lack of authorized on-board spares as reported in CASREPs indicated the existence of ILS problems. MDS narratives were also used to identify ILS problems, since the deferral codes frequently indicated that a particular maintenance action was deferred for lack of spare parts, technical documentation, or training or experience on the equipment. Where ILS problems were identified, previously completed analyses of functionally similar systems or equipments were reviewed to determine if similar ILS problems had been identified. If they had, and if satisfactory solutions had been defined and recommended, those solutions were adopted and documented as recommendations in this report without further detailed analysis. Otherwise, further analysis was conducted to define an appropriate solution.

Each ILS problem was assessed in terms of its significance and the feasibility of successfully implementing a cost-effective solution. Only those solutions judged to be essential and cost-effective were recommended.

2.4.4 Select Effective Solutions

An effective solution was selected by the analyst on the basis of its merit or essentiality with respect to its projected cost and risk. All candidate solutions, whether resulting from this analysis or from previously conducted analyses of functionally similar equipments, that were judged to improve personnel safety or primary mission reliability were assessed on the basis of projected cost and feasibility. If these candidate solutions were not clearly feasible, or if their value, in terms of reduced maintenance burden or improved equipment reliability, was not significant, they were not recommended for implementation.

2.5 TASK 4: DOCUMENT SEA RESULTS

The Task 4 approach was to present the analysis results in a concise, logical format that included an introduction to the SEA objectives, a summary of the technical approach used, a presentation of the analysis results, and a section listing the specific conclusions and recommendations resulting from the analysis. Appendixes were included as necessary to show pertinent data affecting the system, including a table defining the configurations by allowance parts list (APL) number for each LHA-1 and LPH-2 Class hull included in the analysis.

CHAPTER THREE

RESULTS

3.1 SYSTEM DESCRIPTION AND CRITICALITY

The feed and condensate system provides for the supply of feedwater from the deaerating feed tanks (DFT) to the boilers and for the return of the plant condensate to the DFT. On the LHA-1 Class ships, which have two 600-psi steam-driven propulsion plants, there are two complete feed and condensate systems, each supporting a large single boiler. In contrast, the LPH-2 Class ships are single-plant (single-shaft) ships that have one feed and condensate system supporting two smaller 600-psi boilers. In addition, the LHA-1 Class ships have combined engine rooms/fire rooms (two), while the LPH-2 Class ships have a separate engine-room/fire-room design (one each). On both ship classes, redundancy is built into the feed and condensate system(s), so that loss of a single equipment, such as a pump or valve, does not normally degrade the capability of the system or affect the capability of the ship to carry out its various missions.

In addition to being a mission-critical system for both the LHA-1 and LPH-2 Class ships, the feed and condensate system has also proven to be a major maintenance burden at all levels of repair and, in terms of all maintenance significant systems, ranks sixth of 118 shipboard systems (see ARINC Research Publication 2652-11-1-2462) on the LPH-2 Class ships and third of 88 on the LHA-1 Class (see ARINC Research Publication 2653-01-TR-2552).

The major maintenance-significant components of the feed and condensate system are listed below by ship work authorization boundary (SWAB):

- Main Feed Pumps (SWAB 2552)
- Main Feed Booster Pumps and Emergency Feed Pumps (SWAB 2553)
- Main Condensate Pumps (SWAB 2555)
- Auxiliary Condensate Pumps (SWAB 2556)
- Deaerating Feed Tanks (SWAB 2557)
- Valves and Piping (SWAB 2551 and 2554)

In the following discussions, unless specifically stated, identification of an equipment -- e.g., main feed pump -- includes the driver and ancillary equipment such as governor and lube oil system.

3.2 SYSTEM MAINTENANCE BURDEN OVERVIEW

While insufficient data on the LHA-1 Class precluded a comparison of maintenance burdens directly with the LPH-2 Class, Table 3-1 compares the reported LPH-2 Class maintenance burden by level of repair (organizational, intermediate, and depot) for the major components (by SWAB) of the feed and condensate system. Organizational and intermediate maintenance burdens (man-days) were derived from MDS data and represent an "average" reported man-day burden for a typical five-year overhaul cycle for an "average" ship of the class. The depot-level burden shown represents a typical ROH man-day cost for the feed and condensate system based on a review and average of seven recent authorized ROH SARPs for the LPH-2 Class. A review of Table 3-1 leads to the following conclusions:

- In terms of man-day costs over a typical five-year overhaul cycle, depot-level (shipyard) costs represent about 90 percent of the total man-days expended on system maintenance, while organizational- and intermediate-level repairs together account for approximately 10 percent.
- The greatest reported maintenance burden was against the main feed pumps, i.e., 50 percent of all system repairs accomplished during the ROH. In terms of total man-days expended during the nominal five-year period, it represents approximately 48 percent of the total man-days expended at the O, I, and D levels of maintenance.

While the data shown in Table 3-1 must be qualified -- i.e., reported ship's force and IMA man-hours are probably much lower than actual man-hours expended on maintenance -- the depot-level maintenance occurring between ROHs (e.g., RAVs) is also not shown. Still, there are orders-of-magnitude differences. With that caveat in mind, further analysis of the data revealed that while the size and content of the repair package for ROH generally remained consistent from ship to ship, i.e., approximately 2,000 man-days per ROH for the feed and condensate system, the number of repairs reported by ship's force and IMAs varied significantly from ship to ship during the period between ROHs. While some differences in reported maintenance burden between ships might be expected, especially over relatively short periods, e.g., two to three years, it was found that over an approximate ten-calendar-year data period some ships of the LPH-2 Class reported more than twice as many maintenance actions (JCNs) as others did for the feed and condensate system. Parts costs also varied significantly by several orders of magnitude from ship to ship (see Table 3-2). Further review of the data also revealed, as Table 3-3 indicates, that some ships used more IMA support than others. In essence, the review of the reported data differences suggests several

Table 3-1. LPH-2 CLASS - FEED AND CONDENSATE SYSTEM MAINTENANCE BURDEN

SWAB	Nomenclature	Average Man-Days Expended in ROH (Percentage of Total Man-Days)	O&I Man-Days (Percentage of Total O&I Man-Days) (Average for Nominal Five-Year Cycle)	Percentage of Five-Year Overhaul Cycle Man-day Burden		Total
				D	O&I	
2552	Main Feed Pumps	969 (50%)	82 (38%)	44	4	48
2553	Main Feed Booster Pumps and Emergency Feed Pumps	372 (19%)	50 (28%)	17	3	20
2551 and 2554	Valves and Piping	277 (14%)	47 (22%)	13	2	15
2555	Main Condensate Pumps	167 (8%)	24 (11%)	8	1	9
2556	Auxiliary Condensate Pumps	121 (6%)	<1 (<1%)	6	<1	6
2557	DFT	49 (3%)	3 (1%)	2	<1	2
Total Feed and Condensate System		1,955	216	90	10	100

Table 3-2. LPH-2 CLASS FEED AND CONDENSATE SYSTEM BURDEN (1 JANUARY 1971 THROUGH 31 MARCH 1981)		
Ship	Total JCNs	Parts Cost
LPH-2	253	$73,938
LPH-3	207	72,424
LPH-7	142	8,050
LPH-9	320	68,144
LPH-10	223	25,911
LPH-11	191	34,424
LPH-12	257	24,425

possible theories that affect selection of a system maintenance strategy:

- Some ships (feed and condensate systems) simply have more maintenance problems than others, caused by a variety and combination of factors that are difficult to quantify (e.g., human factors, environment).
- The overhaul package may not be "tailored" enough to specific ship repair requirements; i.e., some ships may need many more repairs than others, yet are receiving basically the same repair package for the feed and condensate system.
- There is no direct correlation between the overhaul and the number of maintenance problems (operational reliability) experienced later during the operating cycle; or, if there is, it appears that the more overhauls accomplished, the more repairs during the following operating cycle.
- The quality of overhaul varies significantly from ship to ship and shipyard to shipyard; i.e., some ships required more maintenance between overhauls because they received poor-quality repairs.

The remainder of the analysis will consider the foregoing theories and other factors in determining specific maintenance requirements for the maintenance-significant components of the feed and condensate systems, as well as an overall maintenance strategy for the system.

Table 3-3. SUMMARY OF MDS DATA-FOR FEED AND CONDENSATE SYSTEM

APL	Nomenclature	Applicable Ships	Equipments per Ship	Total Equipment Population	Total Ship Operating Years	Ships Reported	JCNs	Man-Hours			Parts Cost (Dollars)	Average Man-Hours per Equipment per Operating-Year
								Ship's Force	IMA	Total		
016021434	Main Feed Pump	LHA-1 Class	4	20	9.69	5	40	197	188	385	4,218	9.90
016020549		LPH-2, 3, 7	3	9	23.65	3	59	589	990	1,579	2,269	22.30
016020793		LPH-10	3	3	7.10	1	27	359	42	401	1,364	18.80
016020977		LPH-11	3	3	7.82	1	21	93	59	152	6,176	6.50
017990021	Main Feed Turbo	LPH-12	3	3	7.28	1	57	606	226	832	6,432	38.10
017020022	Pump	LPH-9	3	3	7.28	1	26	160	28	188	25,120	8.60
057950179B	Main Feed Pump	LHA-1 Class	4	20	9.69	5	20	111	1	112	64,300	5.00
057950068	Turbine	LPH-2, 3, 7	3	9	23.65	3	60	992	3,740	4,732	7,677	66.80
057950103		LPH-10	3	3	7.10	1	16	496	0	496	12,211	23.30
057950143		LPH-11	3	3	7.82	1	26	233	1	234	3,369	9.97
057960014		LPH-9	3	3	7.28	1	53	498	452	950	2,313	43.50
016021161B	Main Feed	LHA-1 Class	4	20	9.69	5	12	18	994	1,012	4,709	26.70
016020558	Booster Pump	LPH-2, 3, 7	2	6	23.65	3	18	431	547	978	4,502	20.70
016020559		LPH-2, 3, 7	1	3	23.65	3	22	231	189	420	2,180	17.80
016020780		LPH-9, 10	3	6	14.38	2	40	486	695	1,181	13,832	27.40
016020953		LPH-11, 12	3	6	15.10	2	18	217	217	434	7,120	9.60
057950072	Main Feed	LPH-2, 3, 7	1	3	23.65	3	20	421	829	1,250	63,203	52.90
057950089	Booster Pump	LPH-9, 10	1	2	14.38	2	18	472	28	500	2,660	34.80
	Turbine											
174031368B	Main Feed	LHA-1 Class	4	20	9.69	2	3	0	0	0	283	0.00
174750735	Booster Pump	LPH-2, 3, 7	2	6	23.65	1	2	92	120	212	4	4.50
174750813	Motor	LPH-11	3	3	7.82	1	2	1	0	1	24	0.04
174751607		LPH-12	3	3	7.28	1	3	23	0	23	8	1.05
174802441		LPH-9	2	2	7.28	1	4	22	209	231	48	15.90
175503583		LPH-10	2	2	7.10	1	7	17	93	110	2,564	7.70
016031734	Emergency Feed	LHA-1 Class	2	10	9.69	5	16	276	105	381	6,708	19.70
016020831	Pump	LPH-10	1	1	7.10	1	7	41	0	41	279	5.80
016020421		LPH-2, 3, 9	1	3	23.65	4	25	280	134	414	19,436	17.50
016031651		LPH-11	1	1	7.82	1	10	141	1	142	4,481	18.00
016031734		LPH-12	1	1	7.20	1	10	47	16	63	878	8.80
016120041		LPH-7	1	1	8.41	1	9	95	0	95	147	11.30
016021162B	Main Condensate	LHA-1 Class	4	20	9.69	5	12	44	422	466	38,000	12.00
016000394	Pump	LPH-2, 3, 7	2	6	23.65	3	27	275	279	554	3,103	11.70
016020763		LPH-9, 10	2	4	14.38	2	29	774	1,260	2,034	9,032	70.70
016020958		LPH-12	2	2	7.28	1	17	59	151	210	1,437	14.40
016031693		LPH-11	2	2	7.82	1	12	256	194	450	3,329	28.80

(continued)

Table 3-3. (continued)

APL	Nomenclature	Applicable Ships	Equipments per Ship	Total Equipment Population	Total Ship Operating Years	Ships Reported	JCNs	Man-Hours: Ship's Force	Man-Hours: IMA	Man-Hours: Total	Parts Cost (Dollars)	Average Man-Hours per Equipment per Operating-Year
174031379B	Main Condensate Pump Motor	LHA-1 Class	4	20	9.69	1	1	0	0	0	12	0.00
174010229		LPH-2, 3, 7	2	6	23.65	3	7	115	239	354	60	7.50
174751946		LPH-11	2	2	7.82	1	2	1	0	1	23	0.06
174752305		LPH-12	2	2	7.28	1	4	52	3	55	0	3.80
175503587		LPH-10	2	2	7.10	1	3	2	253	254	12	17.90
174802386		LPH-9	2	2	7.28	0	0	0	0	0	0	0.00
016021159B	Auxiliary Condensate Pump	LHA-1 Class	4	20	9.69	2	3	175	0	175	2,055	4.50
016020810		LPH-10	2	2	7.10	1	3	4	0	4	0	0.28
016020959		LPH-12	2	2	7.28	1	1	1	0	1	0	0.07
016031642		LPH-11	2	2	7.82	1	1	0	0	0	16	0.00
016020560		LPH-2, 3, 7, 9	2	8	30.93	2	2	2	0	2	244	0.03
174031366B	Auxiliary Condensate Pump Motor	LHA-1 Class	4	20	9.69	--	0	--	--	--	--	--
175503585		LPH-10	2	2	7.10	1	3	7	0	7	0	0.50
		Note: No other ships reported										
070010147B	DFT	LHA-1 Class	2	10	9.69	5	28	83	68	151	2,899	7.80
074240040		LPH-11	1	1	7.82	1	5	26	97	123	0	15.70
074240026		LPH-2, 3, 7, 9	1	4	30.93	4	29	147	234	381	2,512	12.30
074240034		LPH-10	1	1	7.10	1	9	192	21	213	0	30.00
074240037		LPH-12	1	1	7.28	1	3	18	50	68	0	9.30
Various	System Valves	LHA-1 Class	--	--	9.69	5	75	297	434	731	19,497	--
Various		LPH-2 Class	--	--	53.13	7	245	2,033	3,502	5,535	52,338	--

3.3 MAINTENANCE REQUIREMENT IDENTIFICATION

Each of the maintenance-significant components identified in Section 3.2 was further analyzed, where appropriate, in terms of the following:

- Configuration and operating requirements
- Current maintenance policy/plan
- Maintenance history
- Reliability, maintainability, and availability
- Design deficiencies and improvements
- ILS deficiencies and improvements
- Recommended maintenance strategy

Where possible, comparisons are made with similar or identical equipments on other ship classes where similar analyses have been performed. The primary emphasis is on identifying and validating intermediate- and depot-level maintenance requirements to support the Class Maintenance Plans and to recommend an overall system maintenance strategy. The resulting maintenance recommendations are summarized in Chapter Four, together with other pertinent recommendations such as design improvements and improvements to logistics support that affect maintenance strategy selection.

Discussion of system components following the main feed pump discussion (Section 3.3.1) is generally reduced in detail where similarities in findings among the types of equipments are apparent.

3.3.1 Main Feed Pumps and Turbines

3.3.1.1 Configuration and Operating Requirements

The LHA-1 Class ships have four main feed pumps (two per boiler) with steam turbine drivers. These feed pumps are manufactured by the Warren (pump) and Whiton/Terry (turbine) companies. The LPH-2 Class ships have three main feed pumps and turbines supporting two boilers. These equipments are identified by several different APLs. However, the majority of the pumps and turbines on LPH-2 Class ships are also manufactured by the Warren and Whiton companies (LPH-2, 3, 7, 10, and 11), while LPH-12 has Pacific-built turbo pumps and LPH-9 has Byron Jackson-built pumps and Hardie Tynes turbines. (Appendix B identifies equipment characteristics and manufacturers by APL.) For full-power operations of the main propulsion plant on the LPH-2 Class, two of three main feed pumps are normally required. One of two main feed pumps is required per boiler on the LHA-1 Class ships. Therefore, each ship has sufficient redundancy in the event of a feed pump failure. Emergency feed pumps are also installed on each ship in the event of a main feed pump failure to provide some additional capacity.

3.3.1.2 Current Maintenance Policies

The type commanders' maintenance manuals (COMNAVSURFLANTINST 9000.1 series and COMNAVSURFPACINST 4700.1 series) identify specific testing requirements. For the LHA-1 Class ship, the Plan for Maintenance (PFM) (developed by the ship builder) recommends overhaul "when required" on the pump end to be accomplished by ashore shop 31 (assumed to mean depot level), with all other corrective maintenance to be accomplished on board by ship's force to the piece-part level. The LHA PFM also calls for overhaul of the turbine end "when required," to be accomplished by ship's force, with bearing repair to be performed by ashore shop 31 and all other corrective maintenance to be accomplished by ship's force. The overhaul specified in the PFM, and derived from the Maintenance Engineering Analysis developed on the LHA-1 Class main feed pumps, is less than a class B specification. No class B overhaul requirement is contained in the PFM, nor are any IMA support requirements identified in that document. The preliminary CMP for the LHA-1 Class does identify both IMA and depot-level requirements, including class B overhaul requirements at a frequency of five years to be performed at the depot level of maintenance. The class B overhaul frequency of five years was based on the overhaul history and CMP requirements developed on functionally similar equipments on other ship classes (1200-psi ships). PMS is established for all of the main feed pumps installed on the LHA-1 and LPH-2 Class ships. No Plan for Maintenance exists for the LPH-2 Class, although a Class Maintenance Plan is currently under development for that ship class. As will be discussed later, class B overhauls are being accomplished routinely on all main feed pumps of the LHA-1 and LPH-2 Class ships.

3.3.1.3 Maintenance History Profile

From Table 3-3 it can be seen that the main feed pump (pump and turbine) maintenance burden, as reported by MDS in terms of man-hours, parts cost, and maintenance actions (JCNs), has varied, sometimes significantly, from equipment (APL) to equipment or from ship to ship. However, in general, the ranges of maintenance burden per equipment (normalized to equipment operating years) were similar to those calculated on other ship classes with similar main feed pumps and turbines. An exception is the Byron Jackson (APL 017020022) pump and Hardie Tynes turbine (APL 057960014) combination installed aboard LPH-9. Parts costs for pump repairs and the number of maintenance actions (JCNs) for the turbine end were significantly higher than for those installed on other ships of either class. A review of MDS narratives revealed no conclusive evidence as to why these feed pumps had a relatively higher maintenance burden (approximately twice that of the class average), although they appear to be of a slightly more complex design and several replacements of internal assemblies have been made. In 1976 the ship had requested (JSN EB01 6320) that the pumps be replaced with Pacific-built turbo pumps (similar to those installed on LPH-12, APL 017990021) and cited the history of unreliability of their installed pumps and difficulty in obtaining repair parts as justification. On the basis of a comparison of the historical maintenance burden of the two installations, it is concluded that replacement of the installed main feed pumps on LPH-9 during the next ROH (FY 85) with new pumps may be warranted. The purchase price of a new Pacific turbo pump (NIIN 2346485), as shown in the June 1980 Navy Management Data List (NMDL), was $45,000. This compares with approximately $57,000 (each - excluding associated equipment) for class B overhaul of the LPH-9 main feed pumps and turbines currently installed during the ship's last ROH (FY 80). While it is difficult to compare these costs directly, because of installation requirements and alteration requirements for a new equipment, in view of the past history of the LPH-9 main feed pumps, it may be cost-effective to replace them.

In terms of the types of repairs and primary failure modes associated with the main feed pump and turbine maintenance burden shown in Table 3-3, it was found that the majority of the significant forces afloat maintenance actions (approximately 75 percent) performed between ROH/COHs consisted of overhauls of the pump and turbine, repair of controls (governor, overspeed trip, steam admission valve), repairs to the lube oil system (pump, motor, and lube oil coolers), repairs to associated valves (exhaust, relief, suction, and discharge), and the replacement or rework of wearing rings and thrust and journal bearings. The nature of these repairs is similar to those repairs found on other ship classes, including those of the AFS-1, AOE-1, and AOR-1 Classes. In particular, lube oil problems, alignment problems, and governor problems were the most significant in contributing to main feed pump failures or performance degradation.

In the review of the maintenance history at the ship (organizational), intermediate (IMA), and shipyard (depot) levels of repair, it was found that most repairs could be accomplished at any one of the three levels; i.e., designation of the accomplishing activity depended as much on where the ship was in the operating cycle, its workload, and the attitude of the crew as it did on the capability (expertise) of any particular level of repair (LOR). However, class B (TRS) overhauls are generally accomplished at the depot level of repair. The types and frequencies of repairs, capabilities of the different levels of repair, and some of the rationale for choosing the appropriate LOR are discussed in the following subsections.

Depot-Level Repairs

A review of authorized SARPs and MDS data revealed that each main feed pump and turbine (including associated controls, lube oil system, and other ancillary equipment) is receiving class B overhauls by the shipyards or by the manufacturer at least once during the five-year overhaul cycle, usually during ROH/COH. The average cost per feed pump overhaul, including associated controls, is about 300 man-days, although this cost has varied somewhat depending on the shipyard or the detail of the specification for work (SARP statement) describing the class B overhaul. For example, if a Technical Repair Standard (TRS) was specified, the cost was generally higher. It also appeared that if tasks were aggregated, e.g., turbine and governor overhauled as part of the feed pump overhaul, the cost was lower than when components were identified as separate line litems in the SARP. The cost for main feed pump overhauls by the manufacturer, which are being accomplished under a basic ordering agreement (BOA) with NAVSEA for Terry turbines and Warren pumps, averages about $100,000, equivalent to approximately 400 shipyard man-days). This cost is approximately 25 percent higher than that of the average shipyard class B overhaul. A review of the limited data available on those pumps overhauled under the BOA revealed no conclusive evidence as to whether the overhauls were of better quality than those accomplished by the shipyard, although NAVSEA (PMS-301) has indicated that the overhauls received under the BOA have generally been satisfactory. Ships of the LPH-2 Class receiving overhaul of their main feed pumps under the BOA include LPH-10 (completed in January 1981) and LPH-11 (completed in October 1981). The LPH-3 is also scheduled to receive overhaul of the main feed pumps (two of three) by the manufacturer during the FY82 ROH. A review of the maintenance histories of these pumps, when sufficient data have been accumulated, should provide more insight into the worth of accomplishing such overhauls by the manufacturer.

As shown in Table 3-1, depot-level repair man-days for the main feed pumps appear to represent nearly one-half of the total man-days associated with feed pump maintenance at all levels of repair over an operating cycle, as well as a significant portion of the total feed and condensate system life-cycle maintenance burden. More significantly, these costs are "controllable" in the sense that a policy of not routinely (for insurance purposes) performing class B overhaul at each ROH may represent a significant cost saving; i.e., costs are reduced if it is assumed that wearout and increased failure rate do not occur as a result of not overhauling on a routine basis. In essence, the question is whether routine class B overhauls every ROH are required in order to assure feed pump reliability and availability and whether that is the most cost-effective maintenance strategy.

Further review of the authorized SARPs and MDS data revealed that while the main feed pumps are being routinely overhauled, the documented rationale for overhaul has usually been nonspecific or weak. For example, CSMP items that identified problems such as packing leaks, vibration, or other problems (which do not justify class B overhaul) were sometimes cited as supporting rationale in the authorized SARP for class B overhaul of the pump and turbine. In some instances, ship's force work requests identified the baseline SARP as authority for class B overhaul. In addition, MCA/vibration analysis conducted during the POT&I did not always support the requirement for class B overhaul. In effect, it appeared that class C repairs (i.e., "fix what failed or is about to fail") may have sufficed in many cases, especially in view of the relatively high costs associated with routine class B overhauls and the apparent lack of quality associated with many of the overhauls being accomplished.

Interviews with ship's engineers, as well as a review of MDS and CASREP data, support the finding that the quality of overhaul may vary significantly depending on the shipyard, the personnel accomplishing the overhaul, and other factors, including the quality of available parts, previous modifications made to the equipment, and quality-assurance testing. Lack of adequate test and repair standards (TRS) may also contribute to the variation in the quality of overhaul (initiatives in the area of TRS development are under way under the cognizance of the DART Program). The effect has been apparent in the relatively large number of failures generally occurring soon after overhaul. Evidence is contained in MDS data, and it is the opinion of the ship's engineers interviewed, although there is no conclusive evidence that some of the post-overhaul failures did not occur as a result of operator error or other causes. However, there is also evidence that some higher-quality overhauls are being accomplished as well. For example, SUPSHIP San Diego reported that main feed pumps on FF-1052 Class ships are being successfully overhauled by a private shipyard. SUPSHIP San Diego attributes the success, apparent in the small amount of rework required after overhaul, to a relatively small group of private shipyard employees who have conducted a number of overhauls on the FF-1052 Class ship main feed pumps and have documented the recurring problems and solutions to properly repairing those problems, many of which apply to the main feed pumps installed on the LHA-1 and LPH-2 Class ships (e.g., auxiliary gland exhaust system not operating properly, steam leaking by steam seals, repair parts problems, pump shaft-to-casing misalignment).

The solution to the question of whether routine class B overhauls of the main feed pumps are a cost-effective maintenance strategy is not a clear one based on the data available. On the one hand, there is evidence that because of a variety of factors, the quality of overhauls is lower than what it should be. On the other hand, there are times when the need for class B overhaul on specific feed pumps may exist and the most appropriate level of repair for such an overhaul is the depot level (shipyard or manufacturer). In any event, there is no evidence to suggest that routine class B overhaul assures continued reliability between major maintenance availabilities (ROH/COH). There is also sufficient opportunity during the period between ROHs to accomplish class B overhauls (e.g., during SRAs or RAVs) on selected main feed pumps whose operating performance or material condition warrants such an overhaul.

Organizational- and Intermediate-Level Repairs

From the summary of MDS burden data presented in Tables 3-2 and 3-3, it can be seen that intermediate-level repair activities (e.g., tenders, SIMAs) have been used to support main feed pump repairs for both ship classes, although the majority of repairs (many of which are not reported in MDS if parts are available or deferral is not required) are accomplished by ship's force. Review of MDS narratives, as well as interviews with ship's engineers, led to the conclusion that, with the exception of certain PMS (mandatory) test requirements, most repairs can be accomplished by ship's force if required parts are available. Repair and calibration of governors, overspeed trips, steam admission valves, major pump or turbine repairs, and repair of the lube oil system were the repairs most commonly deferred for outside assistance. Again, there were variations between ships; however, much of the IMA-level assistance was simply required to relieve the ship of its workload. A comparison with ships of other classes, including the AFS-1, AOE-1, CG-16, CG-26, and CV-59 Classes, revealed similar findings. Smaller ships, such as the FF-1052 Class, appear to have less capability, primarily because there are fewer on-board machining capabilities and repair facilities. (Shipboard capabilities are further discussed in Section 3.4.)

In general, most of the repairs accomplished by the IMAs are class C in nature; i.e., they address specific problems and do not generally include major overhauls of main feed pumps and turbines, especially in quantity of multiple numbers. Overhauls in multiple numbers would generally overload most IMAs if they were not performed during ROH/COH or an extended SRA.

Appendix C lists the types of repairs and average repair times associated with the feed and condensate system, including the main feed pumps, at the intermediate (IMA) level of repair. The average IMA-level maintenance burden per ship per operating year can be derived from Table 3-3 by dividing total IMA man-hours by ship operating years. For main feed pumps and turbines on the LPH-2 Class, this figure averages about 80 man-hours per year. Because data on the LHA-1 Class are limited, it is recommended that for the LHA-1 Class 100 man-hours per year per ship be used for planning purposes.

3.3.1.4 RM&A Assessment

While classical calculations of reliability, maintainability, and availability were not possible with the data available, because of inconsistencies or incompleteness in reporting, it is generally concluded that the main feed pumps on both the LHA-1 and LPH-2 Class ships are basically reliable, are maintainable by ship's force, and have a relatively high operational availability in comparison with other ship classes analyzed to date. This conclusion is based primarily on discussions with ship's engineers and maintenance data (MDS and CASREP) comparisons with functionally similar equipments on other ship classes, as well as discussions with personnel within the Navy's technical community. As an example, it was found that only 20 CASREPs were reported on the LPH-2 Class and 10 CASREPs on the LHA-1 Class ships. This is the equivalent of about one CASREP per ship every 2.5 years. Most of the CASREPs were categorized as C-2, which indicates minor degradation of system capability (see Appendix D for a summary of CASREPs).

More specifically, it was found that the majority of main feed pump failures could be attributed to failure of the lube oil system (e.g., pump, motor, lube oil cooler), lube oil contamination, misalignment of the pump and turbine, piping (to casing) misalignments, the overspeed trip system, and control failures (e.g., governor). While some problems are attributable to design, some of these failures and the causes of other failures or repairs could further be attributed to a variety of factors, including operator errors, poor quality of previous overhaul or repairs, use of improper or poor quality parts, or a lack of proper preventive maintenance. In essence, many variables contributed to what might be considered earlier than "normal" feed pump failure. It is also significant that most of the failures occurred in attached components (e.g., lube oil pump, governor). During the operating cycle relatively few failures were reported as requiring complete replacement or rework of the pump or turbine internal rotating assemblies. In addition, there was no apparent rate of wearout of the feed pumps or components observable from the data. Generally, as is indicated by the differences in MDS burden data in Tables 3-2 and 3-3, the number of repairs and associated failures also varied significantly from ship to ship or feed pump to feed pump. The combination of these findings leads to the conclusion that the predictability of needed repairs, i.e., specific repair tasks at specific frequencies, is not possible at the individual ship or equipment level on a long-range basis. Consequently, for long-range planning purposes (e.g., baseline SARP), manpower reservations should be used until specific tasks are defined on specific ships as part of the pre-overhaul test and inspection (POT&I) and the work definition process just prior to or during the initial start of overhaul.

3.3.1.5 Design Deficiencies and Improvements

Feed pump design improvements are under the cognizance of the DART Program, NAVSEA (PMS-301) and NAVSSES, the designated In-Service Engineering Activity (ISEA). With regard to the LHA-1 and LPH-2 Class ships, the design improvements proposed for feed pumps by PMS-301 were reviewed in relation to their maintenance and failure history to determine applicability and projected impact on maintenance strategy recommendations. These design improvements are primarily in the form of shipalts and improved materials procurement (see Appendix G), which are in various stages of implementation across the ship classes.

In general, the improvements developed for main feed pumps were determined to be applicable to the LHA-1 and LPH-2 Class ships on the basis of a review of MDS and CASREPs and the failure modes and causes found. More specifically, those shipalts and other improvements designed to reduce failures associated with or attributable to the lube oil system, alignment problems, and control problems should help to improve main feed pump reliability. However, a review of that maintenance history and discussions with ship's engineers suggest that Shipalt LPH-496 (Electric Overspeed Trip) may require reevaluation. This shipalt has been installed on the LPH-7 and is scheduled for installation on other ships of the class. It is designed to provide an overspeed trip and safety shutdown system capability. A review of the maintenance (MDS) and CASREP histories for the LPH-2 Class revealed no evidence that overspeeding of the steam turbine was ever a problem (on either ship class). However, three CASREPs were reported on the LPH-7 overspeed trip system soon after installation of Shipalt LPH-496K. The ship reported failures of the overspeed trip circuitry on all pumps and attributed the cause to either high ambient temperature (140°F) in the area where the feed pumps and overspeed trip monitors are located or to inadequate design of the magnetic-type pick-up probes used as sensors. Ship's engineers on LPH-7 also reported during a ship visit that the new overspeed trip system was not supported by the COSAL and that the probes were difficult to obtain through the Navy supply system. This lack of parts support was apparently the reason for the three CASREPs to the system. Because of the problems with this system on LPH-7, it is recommended that the need for installation on other ships of the LPH-2 Class be reevaluated. In particular, if the heat stress problem on the LPH-2 Class ships is determined to be the cause of failure of the electric overspeed trip system, that problem should be resolved before further installation of the overspeed trip system on other ships of the class. (See Appendix G for description of Shipalt LPH-496K, related Shipalts LPH-614K and LHA-169K, and other shipalts to improve feed pump reliability.)

Other design defects found could generally be attributed to poor installation. For example, shipalts and modifications installed over the years have added sensing lines and piping, reducing the accessibility of the pumps and turbines for PMS and corrective maintenance. It is recommended that future shipalts and modifications give more consideration to the impact on equipment maintainability, i.e., accessibility for maintenance, and that the shipalt approval process consider maintainability, as well as other logistics considerations, e.g., parts support. For ships of the LHA-1 Class, PERA (ASC) class items were also reviewed; it was found that problems identified in the MDS data generally correlated with those class items identified as design problems. Probably the most significant of these problems is lube oil contamination. On the basis of a review of the data, as well as one of the ship visits (LHA-2), lube oil contamination is a continuing problem -- sometimes requiring daily flushing of the lube oil system. The ship's engineers on LHA-2 reported that the current modification installed to correct the problem, which includes the use of a centrifilter to separate the water from the lube oil, has not solved the problem. NAVSSES is currently investigating to identify a solution.

3.3.2 Main Feed Booster Pumps and Emergency Feed Pumps (SWAB 2553)

Three main feed booster pumps of the centrifugal type, both turbine- and electric-motor-driven, are installed on LPH-2 Class ships, and four electric-driven centrifugal pumps are installed on LHA-2 Class ships. These pumps transfer feedwater from the DFT to the main feed pumps for further transfer to the boiler(s). Like the main feed pumps, all feed booster pumps are supplied by the same manufacturer and are supported by the same APL across the LHA-1 Class ships; those installed on the LPH-2 Class ships are supported by various APLs (see Appendix B). Redundancy and operating requirements are essentially the same as described for the main feed pumps; i.e., two of three pumps are needed for full-power operations on the LPH-2 Class ships, and one of two is needed for each plant on the LHA-1 Class.

For each propulsion plant, a reciprocating steam-driven emergency feed pump is also provided (two per LHA and one per LPH). These pumps are used primarily during plant light-off, for transferring feedwater between tanks, or as an emergency backup pump in the event of a main feed pump failure. However, the emergency feed pump is not essential to steaming of the propulsion plant, and the number of operating hours is relatively low in comparison with the other feed pumps.

Table 3-1 shows that the main feed booster pumps and emergency feed pumps of the LPH-2 Class represent a significant portion of the total feed and condensate system maintenance burden, ranking second behind the main feed pumps within the system; i.e., they represent 19 percent of the total system man-days expended at the depot level and 28 percent of the reported man-days expended at the ship and IMA levels. As Table 3-3 indicates, a significant portion of the maintenance burden and parts cost is expended on the turbine drivers for the feed booster pumps (LPH-2 Class) as compared with the expenditures on the electric motor drivers. On the average, this difference amounted to about four times the number of maintenance actions (JCNs) and man-hours and more than ten times the parts cost per unit when the two different types of drivers (turbine and electric) were compared. The emergency feed pumps, compared with the main feed booster pumps on a per unit basis, generally represented a smaller maintenance burden. Again, comparisons on a ship-to-ship basis for each of the equipments varied significantly in terms of maintenance burden and parts cost.

Most of the significant repairs associated with the maintenance burden for the main feed booster pumps (and turbines) were similar to those for the main feed pumps. Again, the lube oil system, controls, and internal wear due to misalignment of the pump and turbine were the primary causes of failure. For the electric motor drivers, the relatively few repairs noted (in comparison with the turbine drivers) were due primarily to motor controller failures, bearing replacement, and occasional motor burnout (usually caused by moisture, dirty windings, or accidental grounding). The location of these pumps, i.e., near bilge wet areas, is suspected to have contributed to some of these failures, as is operator error and other causes discussed previously.

Emergency feed pump repairs, for the most part, have consisted of overhaul of discharge relief valves and steam admission valves, replacement of the piston or piston rings, repair or replacement of cylinder liners, and repair of some steam chests. Major overhauls of the pumps have occasionally been required during the operating cycle also. Again, no significant differences in the maintenance histories for these equipments were noted in comparison with previous analyses (SMAs/SEAs) on other ship classes with functionally similar equipments.

In contrast to the main feed pumps, it appears that the main feed booster pumps are not routinely receiving class B overhaul during ROH. Review of available SARPs and MDS data shows that approximately half of the main feed booster pumps are being overhauled during ROH. In addition, a review of authorized SARPs showed that a significant number of the main feed booster pumps were deleted from the overhaul packages as a result of MCA findings. In some cases ship's force was also assigned responsibility for overhaul. Therefore, in general, it appears that an on-condition maintenance strategy is being used for depot-level class B overhauls of the main feed booster pumps, although in some instances it appeared that insurance overhauls had been done. The average class B cost for the main feed booster pumps was about 110 man-days, although the man-day costs varied slightly depending on the detail of the class B specification contained in the SARP (e.g., TRS) or on whether the pump overhaul was a separate task from the driver overhaul.

In contrast, emergency feed pumps are routinely given class B overhauls at ROH. Man-day cost at the depot level for this type of pump has varied from 31 to 169 man-days per unit. Again, the more specific the class B specification, the higher the cost. The average class B overhaul cost per emergency feed pump was about 100 man-days.

While there was some evidence of poor quality or ineffectiveness of overhauls for main feed booster pumps and emergency feed pumps in MDS narratives reviewed, and ship engineers interviewed generally complained of the overhauls accomplished by the shipyards, it is concluded that overhaul of these pumps has generally been satisfactory in comparison with post-overhaul histories of the more complex main feed pumps. Again, it is concluded that occasional class B overhauls by the shipyard or replacement of these equipments with new equipments will be required because of modifications that will make replacements of parts difficult; i.e., some "poor quality" parts do not fit because of previous modifications to the equipment (e.g., internal pump assemblies not fitting because of previous rework of the pump casing).

From the MDS burden data presented in Tables 3-2 and 3-3, it is apparent that the IMAs are also making repairs to the main feed booster pumps and emergency feed pumps. Again, it appeared that most of the IMA maintenance actions were accomplished to relieve the ship crews of some of their maintenance burden during scheduled availabilities. Appendix C includes a listing of the types of repairs and times associated with these pumps and drivers. Table 4-1 presents an estimate of the projected IMA-level burden associated with those repairs.

In general, the main feed booster pumps and emergency feed pumps are considered reliable on the basis of a review of the available data, interviews with ship's engineers, and comparisons with similar equipments on other ship classes. An exception may be the turbine-driven pumps installed on the LPH-2, 3, 7, 9, and 10 (APL 057950072 and 057950089), which have exhibited considerably higher maintenance burdens and CASREP rates than the electric motor drivers. Lube oil problems, misalignment, and governor failures appear to be more severe on these pumps, resulting in a relatively high rate of catastrophic failure. Each of the installed pumps (one on each ship) has been CASREPed once during the data period.

All of the equipments are considered maintainable by ship's force, with occasional outside assistance (IMA or depot) required. However, access for both preventive and corrective maintenance of these equipments, in particular the main feed booster pumps, is difficult because of their location.

Both MDS data and CASREP data (see Appendix D) indicate that these equipments also have relatively high operational availability. For example, on the LPH-2 Class ships there were only eight CASREPs on the main feed booster pumps (five on turbine-driven pumps), and on the LHA-1 Class (all of which have electric-motor-driven pumps) three CASREPs were reported (two resulting from motor groundings). This is the equivalent of about one CASREP per ship every three years on the LPH-2 Class, and about one every five years on the LHA-1 Class. Downtimes associated with repairs of these pumps were relatively short.

Only one CASREP was reported by each ship class on the emergency feed pumps, indicating the high availability of these pumps.

3.3.3 Main Condensate Pumps (SWAB 2555)

Both the LHA-1 Class and the LPH-2 Class ships have two electric-driven main condensate pumps for each main condenser; i.e., LHA-1 Class ships have four pumps each, and LPH-2 Class ships have two pumps each. One pump is normally required; therefore, each class has redundancy. Appendix B further identifies these pumps by APL number, manufacturer, and capacity.

As Table 3-1 indicates, the main condensate pumps and their electric motors have accounted for only about 8 percent of the total depot-level feed and condensate system man-day expenditures and 11 percent of reported ship's force and IMA maintenance on the system -- representing an average of about 9 percent of the total man-day expenditures at all levels of repair (O, I, and D).

Essentially, the maintenance history in terms of maintenance burden (at the O and I levels) and the types of failures associated with the main condensate pumps has been nearly identical to that of the electric main feed booster pumps. However, it appears that the main condensate pumps are routinely receiving class B overhaul at ROH, while the electric main feed booster pumps are not. Since the pumps and their drivers are similar in design, it is concluded that routine class B overhaul of the main condensate pumps has not resulted in any significant benefit during the operating cycle.

IMA-level maintenance has been used generally to relieve the ship of some of its maintenance burden. Estimates of annual IMA burden for repairs listed in Appendix C are presented in Chapter Four (Table 4-1).

Review of the few CASREPs reported also indicates high operational availability, which is further indicative of the reliability and maintainability of the main condensate pumps.

3.3.4 Auxiliary Condensate Pumps (SWAB 2556)

There are two electric-driven auxiliary condensate pumps for each auxiliary condenser installed: two on the LPH-2 Class ships and four on the LHA-1 Class ships. Each auxiliary condensate pump is capable of handling the maximum anticipated condensate for the auxiliary condenser it serves. Therefore, redundancy is provided in the event of a pump failure.

As Table 3-1 indicates, the auxiliary condensate pumps and their electric motor drivers represent relatively little maintenance burden in comparison with the other feed and condensate system components -- 6 percent of the depot-level repairs, less than 1 percent of the ship's force and IMA burden, and about 2 percent of all levels of repair combined.

Failure modes are similar to those identified for the electric-driven main feed booster pumps and auxiliary condensate pumps. It is evident from the low maintenance burden and the fact that no CASREPs were reported that ship's force can be expected to accomplish all critical repairs and that the pumps have a very high operational availability. This history is also similar to that of similar auxiliary condensate pumps analyzed on other ship classes.

3.3.5 System Valves (SWABs 2551 and 2554)

In the aggregate, feed and condensate system valves of the LPH-2 Class have represented a significant portion of the total maintenance burden at all levels of repair. While Table 3-1 indicates that valves represent 22 percent of the reported system maintenance burden at the ship and IMA levels of repair, discussions with ship engineers suggest that the percentage may be much higher.

While valve repairs are within the capability of ship's force, the overhaul history indicates that both depot and IMA levels of repair are used to make repairs on large valves, usually four inches and larger. Again, the purpose is primarily to ease the ship's force burden and to obtain better-quality repairs.

During ship visits, it was apparent that some ships had excellent valve maintenance programs and others did not. Therefore, estimates of expected valve maintenance burden are difficult to make. The shipyard burden during ROH has averaged about 277 man-days, consisting primarily of feed system valve overhauls. The IMA burden has been about 50 man-hours per year per system.

3.3.6 Deaerating Feed Heater Tanks (DFT) (SWAB 2557)

One DFT is installed on each LPH-2 Class ship, and two are installed on each LHA-1 Class ship. The DFT heats and deaerates condensate and stores resulting feedwater for use in the propulsion boilers.

As Tables 3-1 and 3-3 indicate, no significant maintenance has been expended on the DFTs. Most repairs have consisted of spray valve overhauls and gauge replacements. No CASREPs were submitted during the data period.

On the basis of the data, continued high availability of the DFT is expected. However, because it is critical to system operation, continued adherence to PMS as specified in the appropriate MIP (see Appendix E) is recommended.

3.3.7 System Corrosion

During the ship visits, feed and condensate system components were also inspected for general corrosion problems. It was found that the ships varied significantly in the quality of their preservation programs within the main machinery spaces. However, corrosion problems affecting the feed and condensate system were commonly found on pump foundations and bolts (especially the feed booster pumps and the condensate pumps), steel valves, fasteners, pipe hangers, and drain lines (especially HP/LP drain lines). Those equipments located near the bilges and in difficult-to-access locations appeared especially prone to corrosion and a lack of preservation.

Appendix F lists NAVSEA-approved corrosion-control systems applicable to the feed and condensate system, as well as task descriptions recommended for accomplishment during maintenance availabilities (usually in conjunction with equipment overhauls).

Among the benefits to be gained from applying the improved corrosion-control systems, in addition to reducing the continuing maintenance (preservation) burden of the ship engineers, may be a reduction in failures as well. For example, piping hanger and foundation bolt failure due to corrosion may be contributing to pump and piping alignment problems. Corroded and failed fasteners on valves increase valve maintenance time, which in the aggregate can be significant.

3.4 SYSTEM ILS DEFICIENCIES AND IMPROVEMENTS

While not the primary focus of this analysis, ILS deficiencies that have a significant impact on the maintenance strategy selection were noted in the following areas:

- Manpower, Personnel, and Training
- Supply Support
- PMS
- MCA

3.4.1 Manpower, Personnel, and Training

A major factor influencing the selection of a maintenance strategy is the amount of manpower available, the quality of the personnel operating and maintaining the equipment, and the availability and quality of training provided to those personnel; i.e., an essential part of the feed and condensate system is the people operating and maintaining it. In addition, the working environment significantly affects both the productivity and quality of maintenance performed.

On the basis of shipboard interviews and review of the data, it was concluded that shipboard repair capabilities have varied significantly, even among ships of the same class. For example, on one ship of the LPH-2 Class, the engineers interviewed took obvious pride in their ability to accomplish repairs and in the apparent good material condition of their equipment. On another ship of the same class, the engineers complained of a lack of on-board capability to repair pumps and valves. This attitude was reflected in the relatively poor appearance and poor material condition of that ship's engineering plant (even though it was a newer ship). A comparison of the maintenance burdens reported by these two ships also correlated with the apparent condition of the equipment; i.e., the latter ship had more than twice as many maintenance actions reported over the 10-year data period.

It is concluded that the causes of such differences in shipboard maintenenace capability are primarily manning shortfalls and variations in the quality of personnel on board. The boiler technician (BT) is a critical rating (because of personnel shortages and quality) within the Navy. The quality of personnel, in terms of both leadership and technical capabilities, may also vary significantly from ship to ship. The Navy's policy of rotating a significant portion of the crew during ROH/COH, combined with the practice of using lower engineering ratings (FNs) for such duties as fire watches rather than the performance of repairs under the supervision of rated personnel, may contribute to a lack of on-board "corporate knowledge" and maintenance capability. For example, it appeared from the data that some recurring repairs on the same equipment were due to improper shipboard repairs -- i.e., the cause of failure was not corrected until the failure occurred again. In addition, the practice of rotating much of the crew during ROH/COH may result in some induced failures during post-overhaul sea trials because of the lack of familiarity with the equipment and operating procedures. All of the ship personnel interviewed complained of undermanning, lack of qualified personnel, and lack of funding and time to attend formal schools, such as the advanced BT/MM schools, which include valve and pump maintenance training modules.

Discussions with the ship's engineers led to the conclusion that a return to more on-board training by Navy or contractor personnel (versus school house training) is needed in pump and valve maintenance. The major benefits cited by personnel interviewed for doing so are as follows: (1) in addition to the training received, personnel can be retrained on board, thereby easing the manning shortage problem; (2) training can be accomplished on those specific equipments which are in need of maintenance; and (3) training can be accomplished on precisely the equipments for which the operator/maintainer is responsible, as opposed to "functionally similar" equipments, which may have dissimilar operating or maintenance characteristics.

To place in perspective the general working conditions under which the boiler technicians (and, to a generally lesser degree, machinist mates) must operate and maintain their equipment (including the feed and condensate system), the comments of ship engineers are summarized in the following paragraphs.

Boiler technicians and nondesignated firemen probably have the worst working conditions aboard ship. These conditions can be characterized as follows:

- Twelve- to 16-hour work days while under way (watch standing plus maintenance time). Watch sections consist of two or three, versus four or five for most other divisions aboard ship.
- Extremely hot, humid, and noisy working conditions (LPH class ships reported fire-room temperatures as high as 135°F).
- Poor ventilation (on LPH-2 Class ships).
- Three- or four-section liberty versus five of six sections for most of the ship's crew. "B" division personnel are also required to stay aboard several hours after arrival in port to shut down the plant, and they must arrive several hours early to light off the plant.
- Much of the maintenance, especially on the LPH-2 Class ships (which is a single-plant ship), not deferrable as on other systems. Maintenance must be accomplished much of the time during normal liberty hours. The single-propulsion-plant design of the LPH-2 Class also reduces time available to conduct underway PMS and corrective maintenance.

Leadership qualities and technical ability of the mid-level petty officers (E-5/6) are generally deficient, aggravating many of the problems associated with operating and maintaining the equipment.

While the solution to these problems is obviously more manpower, higher-quality personnel, and more training, it is also obvious that the Navy recognizes these problems and is attempting to solve them through such initiatives as the steam propulsion improvement project and other initiatives designed to encourage entry into the BT and MM ratings. However, it is also concluded that until these manpower, personnel, and training deficiencies are resolved, the material condition will remain less than what it could be, and hardships will continue to be imposed on those who must operate and maintain the equipment.

3.4.2 Supply Support

While MDS and CASREP data did not indicate major problems in supply support in terms of high parts usage, ship engineers interviewed generally ranked supply support as the most significant problem (next to undermanning and the quality of personnel) affecting the timeliness and quality of maintenance. Of the two ship classes, the LHA-1 Class appears to be better supported in terms of a more up-to-date COSAL and the availability of on-board spares (e.g., complete feed pump governor). However, engineers on both ship classes complained of inaccurate COSALs, which result in time-consuming efforts to identify and obtain the correct parts. One ship of the LPH-2 Class had recently received a COSAL validation, yet still cited COSAL deficiencies and inaccuracies as a problem. In particular, the identification of valves and the availability of pump internal parts appeared to be common problems. Obtaining seldom-replaced parts, such as pump impellers, through normal supply system procedures was described as extremely difficult, apparently resulting in the use (or abuse) of the CASREP system to obtain the necessary parts. Other problems reported were generally concerned with the quality of parts, e.g., poor-quality materials (valves) and poorly fitting parts (shafts, sleeves, wear rings). As mentioned previously, some fit problems associated with parts could be attributed to previous equipment rework or modification.

On the basis of interviews with ship engineers on both ship classes, it is concluded that a significant part of the problem associated with out-of-date COSALs must also be attributed to the lack of engineering manpower. For example, even though a private contractor was responsible for conducting the COSAL validation on the LPH-2 Class ship mentioned earlier, because of the scope of the work, lower-rated, unqualified engineering personnel were used to accomplish much of the on-site validation. Therefore, COSAL accuracy problems persist.

3.4.3 PMS

The PMS for components of the feed and condensate system was reviewed with respect to the corrective maintenance histories for those components (Appendix E identified the MIPs). In general, the PMS is considered adequate and, if accomplished as prescribed, it should eliminate the need for much of the corrective maintenance previously addressed. Ship engineers who were interviewed generally agreed on the adequacy of the PMS and offered two recommendations:

- "Tailor" the PMS more to the specific ships' equipments.
- Change annual or cyclic "open and inspect" requirements to a situational requirement -- i.e., if a problem is suspected, open and inspect to identify the cause and correct it.

The first recommendation is concerned with variations between ship equipments due to improvements, modifications, and differences in configuration. The second recommendation is intended to reduce man-hours associated with open-and-inspect requirements on equipments that are performing well and otherwise appear to be in good material condition. In addition, it is intended to reduce the chance of inducing failures resulting from errors in teardown and reassembly.

It was also noted that lay-up maintenance was not prescribed for all of the rotating machinery within the feed and condensate system. It is recommended that this be done to prevent start-up failures after extended availabilities.

Of all the problems associated with PMS, it still appears that the most significant is lack of accomplishment. Ship engineers interviewed generally agreed that much of the PMS was not accomplished because of a lack of manpower and time. On the LPH-2 Class ships in particular, the single-plant design reduces much of the opportunity for accomplishing PMS while under way, as well as corrective maintenance. On the LHA-1 Class ship visited, engineering manpower was said to be the most significant problem.

3.4.4 MCA

An essential ingredient in a truly effective on-condition maintenance strategy is the application of an effective condition assessment program. Broadly defined, such a program might include (or consider) all aspects of periodic testing, inspections, and performance monitoring of machinery. It might include the requirements of PMS, POT&I, TYCOM routines, INSURV, and other programs concerned with assessing system and equipment condition.

While it is apparent that the current PERA (ASC) MCA program is effective in screening some unwarranted repairs before ROH/COH, as well as in supporting the need for repairs, it is recommended that the program be expanded and improved in order to improve system and equipment availability and reduce the corrective maintenance burden. Some specific recommendations are briefly described below:

- Develop MCA standards or criteria for determining the need for repair of equipments. This entails relating failure modes and causes of failure of a specific type of machinery (e.g., main feed pump) to specific measurement techniques (e.g., vibration levels, alignment measurements, oil analysis).
- Once specific MCA standards have been developed, apply the analysis techniques at the most appropriate level of repair and frequency. For example, vibration analysis may best be accomplished on a continuous or periodic basis aboard ship. This would require establishing baselines (e.g., after overhaul), trending, and determining expected failure points for specific failure modes.

3.5 SYSTEM MAINTENANCE STRATEGY

The analysis findings indicate that the maintenance strategy for repairs of the feed and condensate system shall be an on-condition one -- that is, the assessment of material condition and operating performance would determine the need for repairs (corrective or restorative maintenance).

The on-condition maintenance strategy recommended is applicable to repairs conducted during all maintenance availabilities, at all levels of repair, and to all equipments within the feed and condensate system. For the main feed pumps, emergency feed pumps, and main condensate pumps, this represents a departure from the current policy of routine (insurance) class B overhauls. For other system components it represents a less significant departure, and for some equipments no significant departure from the current policy. An on-condition maintenance strategy also implies improved material condition as a result of fewer overhauls, reduced maintenance costs, and manpower savings through a better determination of the need for repairs and performance of those repairs when needed throughout the operating cycle.

The rationale for adopting the on-condition maintenance strategy for the feed and condensate system is summarized as follows:

- There is a need to reduce unnecessary overhauls and unnecessary failures.
- System redundancy and failure history justify such a strategy.
- The on-board capability of ship's force to accomplish critical repairs, while costly in terms of hardships imposed, has proven effective in ensuring relatively high availability during operating and deployment periods.
- The ability to predict specific repair requirements and frequencies on specific equipments is lacking because of the many variables affecting material condition.
- Significant differences in individual ship and equipment material condition result in different requirements (tasks and manpower) at any particular time.
- Most repairs and overhauls can be conducted at any of the scheduled maintenance availabilities; i.e., none require an extended ROH period.

The effectiveness of the recommended maintenance strategy should be enhanced by improvements in condition assessment procedures such as the development of effective machinery condition analysis standards for determining the need for repair on specific equipments; the development and use of effective installed monitoring devices; and the integration of the procedures and techniques with PMS, POT&I, and other programs concerned with assessing material condition. Together with design and support improvements being implemented and developed, operational availability of feed and condensate system components should improve without an increase (and possibly with a reduction) in maintenance costs.

It may be appropriate here to use an example to provide a better understanding of the concept of on-condition maintenance and how it is applied in the maintenance planning process for anticipating repairs. Chapter Four (Table 4-1) shows that the following anticipated maintenance requirements for main feed pumps have been identified:

- Class B overhaul at the depot level at 120 months (E task)
- Class C repairs (unspecified) at the depot level (nominal 20-month period) (Q task)
- Class C repairs at the IMA level throughout the operating cycle (nominal 12-month period) (Q task)

The rationale for the class B overhaul requirements is as follows:

1. Maintenance and failure history has indicated that routine overhauls at 60-month frequencies have not reduced failures and may have contributed to failures. There has also been no indication of an established wearout rate during that period.

2. The 120-month frequency is established because past repairs and modifications over an extended period will probably drive the need for a return to design specifications at that time, or in some cases it may be necessary to replace the pump with a new one.

3. The task is an E type and designated for depot-level accomplishment because it is significant enough to schedule outside assistance and order potentially long-lead-time materials needed to obtain the best-quality overhaul. It is also necessary to establish a specific frequency so that the closest "window" (availability period) is not missed. The task is categorized as an E type essentially so that planning can be accomplished if the condition of the equipment warrants. In some cases (e.g., a specific feed pump) it may not be required for one reason or another; in other cases it may be required more often than every 120 months.

The basis for the second task -- class C repairs at the depot level -- is that some reservation for manpower should be made for repairs that are required to relieve the ship's force burden. The frequency of 20 months may be changed as the operating schedule dictates and the opportunity for making repairs arises (failures and the need for repairs occur randomly). The task therefore represents the best estimate for depot-level manpower requirements over a specified period. For example, this task may have to take the place of a previous, routine class B overhaul. Further, while the task may be well within the capability of ship's force or an IMA, it is designated depot level because of historical and anticipated workload considerations; i.e., if the workload permits, it may be assigned to ship's force or an IMA.

The third task, class C repairs at the IMA level, is based primarily on historical requirements and also represents a reservation for anticipated manpower over a specified period.

CHAPTER FOUR

CONCLUSIONS AND RECOMMENDATIONS

4.1 CONCLUSIONS

The major conclusions resulting from the analysis of the feed and condensate systems on the LHA-1 and LPH-2 Class ships are as follows:

- The maintenance and failure history, redundancy, and criticality of the main feed pumps, emergency feed pumps, and main condensate pumps do not justify routine class B overhauls at five-year intervals. Given an initial satisfactory-quality overhaul and planned improvements, with proper maintenance during the operating cycle, the feed and condensate pumps should operate successfully with only occasional repairs for a 10-year period before requiring restoration to design specifications.
- An on-condition maintenance strategy that employs the assessment of material condition and operating performance as the basis for determining needed repairs is considered the most appropriate for the feed and condensate system in terms of cost and improved system operational availability. Cost (man-day) savings through reduction of depot-level routine overhauls should be realized through the adoption of such a strategy.
- System material condition and the operational availability of system components can be improved significantly if improvements are made in the areas of manpower, personnel, and training. Supply support is another area where improvements can result in significant increases in system material condition and operational availability.
- The operational availability of main feed boiler pumps may be improved, maintenance burden reduced, and life-cycle maintenance costs reduced by replacing feed booster pump turbine drivers installed on some LPH-2 Class ships with electric motor drivers.
- Improved operational availability of main feed pumps installed on LPH-9 should be attained if they are replaced with new main feed pumps. This replacement may also be more cost-effective than a class B overhaul of the existing pumps.

- PMS, with some improvements, is generally adequate. Design and support improvements proposed by the DART Program should generally improve material condition and operational readiness, with perhaps the possible exception of Shipalt LPH 496K. This shipalt should be reevaluated to determine whether it can be cost-effective.

4.2 RECOMMENDATIONS

Recommendations for depot and IMA corrective and restorative maintenance are summarized in Table 4-1. The recommendations are based on the findings and conclusions of this analysis and therefore represent anticipated maintenance requirements assuming adoption of the on-condition maintenance strategy described. It is suggested that the recommended maintenance requirements be incorporated in the LHA-1 Class and LPH-2 Class Maintenance Plans.

The types of maintenance tasks are categorized as follows:

- E Tasks - Engineered work items that should be carefully considered for accomplishment at the proposed frequency to enable the ship to fulfill its mission. The tasks result from either a long history of experience in system operation or a System Engineering Analysis. The E tasks are generally limited to the ship's critical systems.
- R Tasks - Routine work items accomplished whenever the opportunity is presented (such as drydock work) or for work performed on a repetitive basis to support industrial work such as staging, temporary services, and technical support.
- M Tasks - Mandatory work items accomplished to comply with NAVSEA and Type Commander instructions.
- I Tasks - Inspections accomplished to comply with NAVSEA or Type Commander instructions.
- T Tasks - Tests or inspections performed during one maintenance availability in order to define maintenance requirements to be performed during a subsequent availability. T tasks may also include certain tests/inspections to be performed during the operational period prior to the start of a scheduled maintenance availability.
- Q Tasks - Qualified estimates. These consist of all maintenance actions to be performed on condition. They represent a reservation for manpower and generally are related to the accomplishment of corrective maintenance.

Other improvements to the feed and condensate system are categorized as follows:

- Maintenance Strategy Improvements
  - PMS changes
  - Policy

Table 4-1. RECOMMENDED DEPOT AND IMA CORRECTIVE AND RESTORATIVE ACTIONS

Task Number			Component or System	Quantity per Ship	Task Description	Level of Repair	Repair Estimate (Man-Days)	Task Frequency (Months)*	Reference Section
Task Type	SWAB	Number							
E	2552	1	Main Feed Pump	3 (LPH) 4 (LHA)	Perform class B overhaul on the main feed pump, including pump, turbine, governor, lube oil system, and other ancillary equipment in accordance with the applicable TRS (or as specified).	Depot	300 (per unit)	120	3.3 3.5
Q	2552	2	Main Feed Pump	---	Accomplish class C repairs (as specified).	Depot**	60 (LPH) 80 (LHA)	20	3.3 3.5
Q	2552	3	Main Feed Pump	---	Accomplish class C repairs (as specified).	IMA**	10 (LPH) 12 (LHA)	12	3.3 3.5
E	2553	1	Main Feed Booster Pump	3 (LPH) 4 (LHA)	Perform class B overhaul on the main feed booster pump, turbine, motor, and ancillary equipment in accordance with the applicable TRS (or as specified).	Depot	110 (per unit)	120	3.3 3.5
Q	2553	2	Main Feed Booster Pump	---	Accomplish class C repairs (as specified).	Depot**	30 (LPH) 40 (LHA)	20	3.3 3.5
Q	2553	3	Main Feed Booster Pump	---	Accomplish class C repairs (as specified).	IMA**	10 (LPH) 12 (LHA)	12	3.3 3.5
E	2553	4	Emergency Feed Pump	1 (LPH) 2 (LHA)	Perform class B overhaul on the emergency feed pump and ancillary equipment in accordance with the applicable TRS (or as specified).	Depot	100 (per unit)	120	3.3 3.5
Q	2553	5	Emergency Feed Pump	---	Accomplish class C repairs (as specified).	Depot**	5 (LPH) 10 (LHA)	20	3.3 3.5
Q	2553	6	Emergency Feed Pump	---	Accomplish class C repairs (as specified).	IMA**	3 (LPH) 6 (LHA)	12	3.3 3.5
E	2555	1	Main Condensate Pump	2 (LPH) 4 (LHA)	Perform class B overhaul on the main condensate pump, including pump, motor, motor controller, and ancillary equipment in accordance with the applicable TRS (or as specified).	Depot	80 (per unit)	120	3.3 3.5
Q	2555	2	Main Condensate Pump	---	Accomplish class C repairs (as specified).	Depot**	10 (LPH) 20 (LHA)	20	3.3 3.5
Q	2555	3	Main Condensate Pump	---	Accomplish class C repairs (as specified).	IMA**	3 (LPH) 6 (LHA)	12	3.3 3.5

*See Section 4.2 for definition of task frequency for specific task types.
**Level of repair is dependent on manpower and time available.

(continued)

Table 4-1. (continued)

Task Number			Component or System	Quantity per Ship	Task Description	Level of Repair	Repair Estimate (Man-Days)	Task Frequency (Months)*	Reference Section
Task Type	SWAB	Number							
E	2556	1	Auxiliary Condensate Pumps	2 (LPH) 4 (LHA)	Perform class B overhaul on the auxiliary condensate pump, motor, and ancillary equipment in accordance with applicable TRS (or as specified).	Depot	80 (per unit)	120	3.3 3.5
Q	2551 and 2554	1	Feed and Condensate System	---	Accomplish repairs as required on feed and condensate system valves and piping.	Depot**	100	20	3.3 3.5
		2	Valves and Piping	---					
Q	2551 and 2554	3	Feed and Condensate System	---	Accomplish repairs as required on feed and condensate system valves and piping.	IMA**	10	12	3.3 3.5
		4	Valves and Piping	---					
Q	2557	1	DFT	---	Accomplish repairs as required on DFT, spray valves, and ancillary equipment.	Depot**	20	20	3.3 3.5

*See Section 4.2 for definition of task frequency for specific task types.
**Level of repair is dependent on manpower and time available.

- Design Improvements
  - Recommended shipalts, ordalts, and field change
  - Recommended equipment redesign or replacement
- Support Improvements
  - ILS improvements
  - Maintenance-capability improvements

These recommended improvements are summarized in Table 4-2.

Table 4-2. RECOMMENDATIONS

Item	Recommendation	Cognizant Organization	Reference Section
Maintenance Strategy Improvements			
Feed and Condensate System	• Use an on-condition maintenance strategy for feed and condensate system repair and overhaul determination.	NAVSEA PERA TYCOMs	3.6 and Table 4-1
	• Incorporate improved corrosion-control techniques.	TYCOMs PERA	3.3.7
Feed and Condensate System Pumps	• Extend the time between depot-level overhauls (for planning purposes) to a period of 10 years. Overhaul the pump, motor, turbine, and other ancillary equipment as a unit in accordance with the applicable TRS or as otherwise determined to be necessary on the basis of condition assessment.	NAVSEA PERA TYCOMs	3.3 and Table 4-1
	• Increase outside assistance to ship's force for high-burden, repetitive tasks or nonskilled tasks (e.g., fire watches) during ROH/COH.	TYCOMs	3.4
	• Change PMS requirements that specify annual or cyclic "open and inspect" to situational requirements based on condition assessment.	NAVSEA	3.4
	• Specify lay-up maintenance requirements in PMS.	NAVSEA	3.4
ILS Improvements			
Feed and Condensate System	• Continue or increase efforts to obtain necessary manpower, improve the quality of personnel and the availability of training in the BT & MM ratings.	OPNAV	3.4
	• Continue or increase efforts to improve supply support documentation (COSAL) and the quality and availability of spare parts.	NAVSUP NAVSEA Ships	3.4
	• Continue efforts to develop and improve Machinery Condition Assessment (MCA) techniques, with the objective of providing more on-board or installed capability.	NAVSEA	3.4
Design Improvements			
Main Feed Pumps	• Reevaluate the design of overspeed trip shipalts on LPH-2 Class ships.	NAVSEA NAVSSES	3.3
	• Emphasize maintainability/accessibility and parts support in the design and installation of shipalts.	NAVSEA NAVSSES	3.3 3.4
	• Investigate the need for replacement of main feed pumps on LPH-9 with more reliable pumps/turbines.		
Main Feed Booster Pumps	• Investigate replacement of turbine drivers for main feed booster pumps with electric motor drivers on LPH-2 Class ships.	NAVSEA NAVSSES	3.3

APPENDIX A

SYSTEM BOUNDARIES FOR FEED AND CONDENSATE
SYSTEM ON LHA-1 AND LPH-2 CLASS SHIPS

This appendix comprises portions of the SWAB description pages excerpted from a copy of ship work authorization boundaries for surface ships, NAVSEA 0909-LP-098-6010, dated March 1981. It defines the boundaries of the feed and condensate system and was used as a primary reference source in establishing the system boundaries for this analysis.

The major components subjected to analysis in this report are listed below within their respective SWAB groups:

SWAB: 2551

SWLIN: 2551X Title: Main Feedwater Piping and Accessories

Includes authorized work for:

Piping from deaerating feed tank to main feed booster pump inlet flange, from main feed booster pump outlet flange to main feed pump inlet flange, from main feed pump outlet flange to boiler economizer inlet flange, from economizer outlet flange to boiler steam drum inlet flange; from feed tank outlet flange to main feed booster pump inlet flange, from feed tank outlet to emergency feed pump inlet flange, from emergency feed pump outlet to boiler economizer, from emergency feed pump to the deaerating feed tank, from reserve feed and transfer pump outlet flange to deaerating feed tank, from transfer pump to boiler fill flange.

Associated Equipment:

Boiler feed compound tank	Orifices
Chemical injection system	Regulators
Coupling	Relief valves
Demineralizer system	Sample water cooler
Filters	Sound isolation
Gauges	Sway braces
Hangers	Thermometers
Manifolds	Valves
Operating gear	

SWAB: 2552

SWLIN: 2552X   Title: Main Feed Pump

Includes authorized work for:

Turbine-driven main feed pumps from steam inlet flange to exhaust flange, pump suction flange to discharge flange, cooling water inlet flange to cooling water outlet flange.

Motor-driven main feed pump from controller to motor to coupling.

Associated Equipment:

Attached lube oil pumps	Low suction trip
Auxiliary lube oil pumps	Lube oil strainers
Controllers	Motors
Coolers	Pumps
Couplings	Reduction gears
Exhaust/relief valves	Relief valves
Filters	Resilient mounts
Foundation	Sump
Gauges and gauge lines	Switches
Governor	Thermometers
Hand lube oil pump	Turbines
	Valves

SWAB: 2553

SWLIN: 2553X   Title: Main Feed Booster Pump, Emergency Feed Pump

Includes authorized work for:

Turbine-driven main feed booster pump from steam inlet flange to exhaust flange, pump suction flange to discharge flange, cooling water inlet flange to cooling water outlet flange.

Motor drive from controller to motor to coupling.

Emergency feed pumps from steam inlet flange to exhaust flange, from pump suction flange to discharge flange.

Associated Equipment:

Attached lube oil pump	Lube oil strainer
Controllers	Main steam chest
Coolers	Motors
Couplings	Priming pumps
Foundations	Reduction gears
Gauges and gauge lines	Relief valves
Governors	Resilient mounts

Steam cylinders	Turbines
Switches	Vacuum valves
Tank, priming	Valve operating gear
Thermometers	

SWAB: 2554

SWLIN: 2554X Title: Main and Auxiliary Condensate Piping and Accessories

Includes authorized work for:

Piping from main and auxiliary condenser outlet flanges to condensate pump inlet flanges, from condensate pump outlet flanges to air ejector condenser inlet flanges, from air ejector condenser outlet flanges to deaerating feed tank, condensate inlet flange from outlet side of air ejector condenser to condenser inlet flanges, from intercondenser of main air ejector condenser to main condenser inlet flange, condensate crossover line from air ejector condenser to deaerating feed tanks, from reserve feed tanks to condenser make-up feed inlet flanges.

Associated Equipment:

Expansion joints	Operating gear
Filters	Strainer
Gauges	Sway braces
Hangers	Thermal control valves
Indicator	Thermometers
Loop seal	Valves

SWAB: 2555

SWLIN: 2555X Title: Main Condensate Pumps

Includes authorized work for:

Turbine-driven main condensate pump from steam inlet flange to exhaust flange, pump suction flange to discharge flange, cooling water inlet flange to cooling water outlet flange.

Motor drive from controller to motor to coupling.

Associated Equipment:

Controllers	Motors
Couplings	Pumps
Foundations	Resilient mounts
Gauges and gauge lines	Switches
Lube oil strainers	Valves

SWAB: 2556

SWLIN: 2556X Title: Auxiliary Condensate Pumps

Includes authorized work for:

Motor-driven auxiliary condensate pumps from controller to motor to pump, from suction flange to discharge flange.

Associated Equipment:

Controllers	Motors
Couplings	Pumps
Foundation	Resilient mounts
Gauges and gauge lines	Switches
Lube oil strainers	Valves

SWAB: 2557

SWLIN: 2557X Title: Deaerating Feed Tank

Includes authorized work for:

Deaerating feed tank from condensate inlet flange to:

tank discharge flange
steam inlet flange
feed booster pump recirculating connection
main feed pump recirculating connection
high pressure drain connection
whistle drain connection
air outlet connection
tank drain connection

Associated Equipment:

Automatic check valve	Strainers
Baffles	Tank insulation
Deaerating unit	Thermometers
Foundation	Vacuum relief valve
Gauges and gauge lines	Vent condenser
Manual check valve control	Water level float control valves
Shell	Water level gauge glasses
Spray valves	

APPENDIX B

INSTALLATION CONFIGURATION OF FEED AND CONDENSATE SYSTEM FOR THE LHA-1 CLASS AND LPH-2 CLASS SHIPS

The feed and condensate systems discussed in this report are composed principally of the components listed in Table B-1. The table provides detailed information regarding the individual component nomenclature, APL number, hull applicability, and number of components installed on each hull. In some instances it appears from the table that particular key components are not installed on some of the ships. In those instances one of the following conditions exists:

- The component has no separate APL.
- The component is not listed in the applicable type commander's COSAL, and no data were reported in MDS or CASREP data for that component.

Table B-1. COMPONENTS OF THE FEED AND CONDENSATE SYSTEM

Nomenclature (As Listed in APL)	APL/CID	Quantity by Hull Number											
		LHA					LPH						
		1	2	3	4	5	2	3	7	9	10	11	12
Motor AC, 10 HP, 1750 RPM, G.E.	174802441									2			
Motor AC, 10 HP, 1750 RPM, G.E.	175503583										2		
Pump, Main Feed Booster, CTFGL, 280 GPM, Warren	016020952											3	3
Coupling Shaft Flex. Max. Bore 1.437 Grid, Falk	782350003											3	3
Motor AC, 10 HP, 1750 RPM, Reliance	174750813											3	
Motor AC, 10 HP, 1750 RPM, Reliance	174751607												3
Pump, Main Feed Booster, CTFGL, 710 GPM, Warren	016021161B	4	4	4	4	4							
Motor AC, 25 HP, 1800 RPM, Allis Chalmers	174031368B	4	4	4	4	4							
Pump, Main Condensate, CTFGL, 240 GPM, Allis Chalmers	016000394						2	2	2				
Motor AC, 30 HP, 1750 RPM, Allis Chalmers	174010229						2	2	2				
Pump, Main Condensate, CTFGL, 240 GPM, Warren	016020763									2	2		
Coupling Shaft Flex. Max. Bore 1.625 Grid SPR, Falk	782350004									2	2		
Motor AC, 20 HP, 1735 RPM, Westinghouse Electric	174802386									2			
Motor AC, 20 HP, 1755 RPM, G.E.	175503587										2		
Pump, Main Feed, CTFGL, 250 GPM, Pacific Pumps	017990021												3
Pump, Main Feed, CTFGL, 588 GPM, Warren	016021434B	4	4	4	4	4							
Turbine, Steam, Aux. Mn. Feed, Terry	057950179B	4	4	4	4	4							

(continued)

Table B-1. (continued)

Nomenclature (As Listed in APL)	APL/CID	Quantity by Hull Number											
		LHA					LPH						
		1	2	3	4	5	2	3	7	9	10	11	12
Coupling Shaft Flex. Max. Bore .875 INSR, Lovejoy	780130049	4	4	4	4	4							
Pump, Main Feed Booster, CTFGL, 250 GPM, Warren	016020558						2	2	2				
Coupling Shaft Flex. Max. Bore 1.437 Grid SPR, Falk	782350003						2	2	2				
Motor AC, 7.5 HP, 1750 RPM, Reliance	174750735						2	2	2				
Pump, Main Feed Booster, CTFGL, 250 GPM, Warren	016020559						1	1	1				
Coupling Shaft Flex. Max. Bore 1.437 Grid SPR, Falk	782350003						1	1	1				
Turbine, Steam, MFBP, Terry	057950072						1	1	1				
Pump, Main Feed Booster, CTFGL, 280 GPM, Warren	016020780									3	3		
Coupling Shaft Flex. Max. Bore 1.437 Grid SPR, Falk	782350003									3	3		
Turbine Steam, AUX MN FD X BSTR PMP, Terry	057950089									1	1		
Pump, Main Feed, CTFGL, 220 GPM, Warren	016020549						3	3	3				
Coupling Shaft Flex. Max. Bore 2.000 INTNL GR, Koppers	780150001						3	3	3				
Turbine, Steam, Main Feed Pump, Terry	057950068						3	3	3				
Pump, Main Feed, CTFGL, 250 GPM, Byron Jackson	017020022									3			
Turbine, Steam, MFP, Hardie-Tynes	057960014									3			
Bearing Assy THR, Waukesha	370030016									3			

(continued)

Table B-1. (continued)

Nomenclature (As Listed in APL)	APL/CID	Quantity by Hull Number											
		LHA					LPH						
		1	2	3	4	5	2	3	7	9	10	11	12
Filter FDPRESS MDL EFS, AMF	480060220									3			
Overspeed Trip System, Signals & Systems, Inc.	611790004									3			
Pump, Main Feed, CTFGL, 250 GPM, Warren	016020793										3		
Coupling Shaft Flex. Max. Bore 2.125 INTNL GR, Koppers	780150037										3		
Bearing ASSY THR, Kingsbury	370010249										3		
Turbine, Main Feed Pump, Terry	057950103										3		
Pump, Main Feed, CTFGL, 250 GPM, Warren	016020977											3	
Coupling Shaft Flex. Max. Bore 2.125 INTNL GR, Koppers	780150037											3	
Bearing ASSY THR, Kingsbury	370010249											3	
Turbine, Steam, Main Feed, Terry	057950143											3	
Pump, Main Condensate, CTFGL, 240 GPM, Worthington	016021693											2	
Coupling Shaft, Flex. Max. Bore 1.625 INTL GRID, Sier-Bath	780200031											2	
Motor AC, 20 HP, 1800 RPM, Reliance	174751946											2	
Pump, Main Feed Condensate, CTFGL, 240 GPM, Warren	016020958												2
Motor AC, 20 HP, 1740 RPM, Reliance	174752305												2
Pump, Main Condensate, CTFGL, 425 GPM, 1175 RPM, Warren	016021162B	4	4	4	4	4							

(continued)

Table B-1. (continued)

Nomenclature (As Listed in APL)	APL/CID	Quantity by Hull Number											
		LHA					LPH						
		1	2	3	4	5	2	3	7	9	10	11	12
Motor AC, 30 HP, 1200 RPM, Allis Chalmers	174031379B	4	4	4	4	4							
Pump, Aux. Condensate, CTFGL, 60 GPM, Warren	016020560						2	2	2	2			
Pump, Aux. Condensate, CTFGL, 60 GPM, Warren	016020810										2		
Motor AC, 7.5 HP, 1760 RPM, G.E.	175503585										2		
Pump, Aux. Condensate, CTFGL, 60 GPM, Worthington	016031642											2	
Pump, Aux. Condensate, CTFGL, 60 GPM, Warren	016020959												2
Pump, Aux. Condensate, 60 GPM, 1760 RPM, Warren	016021159B	4	4	4	4	4							
Motor AC, 7.5 HP, 3600 RPM, Allis Chalmers	174031366B	4	4	4	4	4							
Pump, Emergency Feed, RCIPG, 180 GPM, Warren	016020421						1	1	1	1			
Pump, Emergency Feed, RCIPG, 180 GPM, Warren	016020831										1		
Pump, Emergency Feed, RCIPG, 200 GPM, Worthington	016031651											1	
Pump, Emergency Feed, RCIPG, 180 GPM, Worthington	016031734	2	2	2	2	2							1
Heater Deartg Cap 210,000 lbs/H (DFT), Worthington	074240026						1	1	1	1			
Heater Deartg Cap 210,000 lbs/H (DFT), Worthington	074240034										1	1	
Heater Deartg Cap 210,000 lbs/H (DFT), Worthington	074240037												1
Heater, Feed, Deartg Cap 370,969 lbs/H, Aquachem, Inc. (DFT)	070010147B	2	2	2	2	2							

APPENDIX C

IMA REPAIR ESTIMATES FOR FEED AND CONDENSATE SYSTEM COMPONENTS

Table C-1 lists repair tasks and repair times for specific components of the feed and condensate system.

Table C-1. IMA REPAIR ESTIMATES FOR FEED AND CONDENSATE SYSTEM COMPONENTS

Nomenclature	Task	Man-Hours per Task
Main Feed Pump	Overhaul pump	312
Main Feed Pump Turbine	Overhaul turbine	280
Main Feed Pump Turbine	LAG turbine	72
Bearings (Thrust, Journal)	Cast bearing	20-40
Babbitt Bearings	Babbitt bearing	100
Pump Casing (Close-Coupled)	Manufacture casing Restore casing	108 up to 194
Pump Casing (Split Casing)	Manufacture casing Restore casing	412 up to 276
Shaft Sleeve	Manufacture shaft sleeve Ceramic coat and grind shaft sleeve	40 16
Impeller Wear Ring	Manufacture new impeller wear ring	12
Impeller	Manufacture impeller	40-48
Shaft	Manufacture new shaft Restore shaft	80 12-40
Valves (Gate & Globe)	Machine valves (re-seat, etc.)	8-20
Valve Stems	Build-up or manufacture	8-24
Main Feed Booster Pump	Overhaul pump	180
Main Feed Booster Pump Turbine	Overhaul turbine	280
Main Feed Booster Pump Motor	Overhaul and rewind motor	120
Emergency Feed Pump	Overhaul pump	224
Main Condensate Pump	Overhaul pump	180
Main Condensate Pump Motor	Overhaul and rewind motor	120
Auxiliary Condensate Pump	Overhaul pump	140
Auxiliary Condensate Pump Motor	Overhaul and rewind motor	120
Governors (Mechanical and Hydraulic)	Overhaul governor	128
Governor Valve	Overhaul governor valve	24

(continued)

Table C-1. (continued)		
Nomenclature	**Task**	**Man-Hours per Task**
Steam Admission Valve	Overhaul valve	176
Lube Oil Pump (Attached)	Overhaul L.O. pump	40
Lube Oil Pump Motor	Overhaul and rewind motor	60
Lube Oil Strainer	Overhaul L.O. strainer	42
Overspeed Trip (not electric)	Overhaul overspeed trip	30
Relief Valves (2" and down)	Overhaul valve	2
(over 2")	Overhaul valve	10
Globe Valves	Overhaul valve	5
Water Regulating Valves	Overhaul valve	24
LP Gate Valves	Overhaul valve	40
Check Valves (1½" and below)	Overhaul valve	8
(2" and over)	Overhaul valve	16
Exhaust/Relief Valve	Overhaul valve	24-36
Spray Valves (D.F.T.)	Overhaul valve	2
Butterfly Valves	Overhaul valve	3
Regulators	Overhaul regulator	24
Valve Manifold	Overhaul valve manifold	48
HP Gate and Globe Valves (Seal Ring)	Overhaul valve	48
Valves (Corrosion Protection)	Metal spray valve body and bonnet	.5-2

Note: Valves requiring hard surface build-up -- add 30 man-hours.

APPENDIX D

CASREP SUMMARY

This appendix summarizes the CASREP data for components of the feed and condensate systems installed on LHA-1 and LPH-2 Class ships.

Table D-1. LPH-2 CLASS CASREP SUMMARY					
Reason for CASREP	Number of CASREPs	Downtime (Hours)			Percentage of Total CASREPs
		Supply	Maintenance	Total	
Main Feed Pumps					
Lube Oil System	5	0	2,819	2,819	25
Governor, Overspeed Trip, Steam Admission Valve	8	1,229	2,581	3,810	40
Internal Wear/ Misalignment	3	0	4,752	4,752	15
Bearing Failure	2	0	1,799	1,799	10
Labyrinth Seal Leaks	1	0	1,359	1,359	5
Exhaust/Relief Valve	1	341	691	1,032	5
Totals	20	1,570	14,001	15,571	100
Main Feed Booster Pumps					
Lube Oil System	2	1,952	1,276	3,228	22
Governor	1	1,344	89	1,433	11
Flexible Coupling/ Misalignment	1	50	199	249	11
Internal Wear/ Misalignment	4	4,409	2,882	4,291	45
Motor/Ground	1	0	305	305	11
Totals	9	7,755	4,751	11,756	100
Emergency Feed Pump					
Internal Wear	1	1,136	0	1,136	100
Main Condensate Pump					
Motor/Ground	2	0	259	259	67
Bearing	1	0	978	978	33
Totals	3	0	1,237	1,237	100

Table D-2. LHA-1 CLASS CASREP SUMMARY

Reason for CASREP	Number of CASREPs	Downtime (Hours)			Percentage of Total CASREPs
		Supply	Maintenance	Total	
Main Feed Pumps					
Lube Oil System	4	480	2,098	2,578	40
Governor, Overspeed Trip, Steam Admission Valve	1	0	166	166	10
Internal Wear/ Unknown	1	0	131	131	10
Bearing Failure	1	144	163	307	10
Mechanical Seals (Accident)	2	0	131	131	20
Broken Shaft/ Misalignment	1	0	3,642	3,642	10
Totals	10	624	6,331,	6,955	100
Main Feed Booster Pumps					
Motor Grounded	2	0	254	254	67
Pump Seized/Unknown	1	0	472	472	33
Totals	3	0	726	726	100
Emergency Feed Pump					
Pump Liner Blocked Exhaust/Entry Port (Due to Overhaul)	1	0	74	74	100
Main Condensate Pump					
Bearing Failure (Pump)	1	0	266	266	100

APPENDIX E

PMS SUMMARY

Table E-1 lists the Maintenance Index Pages (MIPs) applicable to the feed and condensate system components that were maintenance-significant.

Table E-1. FEED AND CONDENSATE SYSTEM PMS SUMMARY (MIP APPLICABILITY)

Nomenclature	MIP	APL/CID	Hull Applicability
Main Feed Pump	F13/101-91 F13/63-88 F13/28-99 F13/28-99	016021434B 016020549 016020793 016020977	LHA Class LPH-2, -3, -7 LPH-10 LPH-11
Main Feed Turbo Pump	F13/45-89	017990021	LPH-12
Main Feed Pump Turbine	F13/101-91 F13/63-88 F13/28-99 F13/28-99 F13/71-79	057950179B 057950068 057950103 057950143 057960014	LHA Class LPH-2, -3, -7 LPH-10 LPH-11 LPH-9
Main Feed Booster Pump	F14/45-11/48 F14/23-A8 F14/22-96 F14/22-96 F14/23-A8 F14/23-A8 F14/22-96 F14/22-96	016021161B 016020558 016020559 016020780 016020780 016020953 057950072 057950089	LHA Class LPH-2, -3, -7 LPH-3, -7 LPH-9, -10 LPH-9, -10 LPH-11, -12 LPH-2, -3, -7 LPH-9, -10
Main Feed Booster Pump Motor	EL-4/28-88	174031368B 174750735 174750813 174751607 174802441 175503583	LHA Class LPH-2, -3, -7 LPH-11 LPH-12 LPH-9 LPH-10
Emergency Feed Pump	F7/58-58	016031734 016020831 016020421 016031651 016031734 016120041	LHA Class LPH-10 LPH-2, -3, -9 LPH-11 LPH-12 LPH-7
Main Condensate Pump	E6/139-30/52 E6/60-10 E6/81-30 E6/132-60 E6/34-20	016021162B 016000394 016020763 016020958 016031693	LHA-1 thru -4 LPH-2, -3, -7 LPH-9, -10 LPH-12 LPH-11
Main Condensate Pump Motor	EL-4/28-88	174031379B 174010229 174751946 174752305 175503587 174802386	LHA Class LPH-2, -3, -7 LPH-11 LPH-12 LPH-10 LPH-9

(continued)

Table E-1. (continued)			
Nomenclature	MIP	APL/CID	Hull Applicability
Auxiliary Condensate Pump	F-14/45-48	016021159B 016020810 016020959 016031642 016020560	LHA Class LPH-10 LPH-12 LPH-11 LPH-2, -3, -7, -9
Auxiliary Condensate Pump Motor	EL-4/28-88	174031366B 175503585	LHA Class LPH-2 Class
DFT	F27/37-30	070010147B 074240040 074240026 074240034 074240037	LHA Class LPH-11 LPH-2, -3, -9 LPH-10 LPH-12

APPENDIX F

CORROSION CONTROL TECHNIQUES

Table F-1 presents recommended SARP work statements for applying NAVSEA-approved corrosion-control systems. Table F-2 provides specific guidance items for applying the corrosion-control systems to common components within the feed and condensate system.

Table F-1. RECOMMENDED CORROSION CONTROL SARP STATEMENTS

SWAB	Problem Area/Components	Recommended SARP Statement	Alternate Corrosion-Control System
2552	Pumps, Main Feed	When main feed pumps are removed from the ship for overhaul or replacement, apply wire sprayed aluminum with low-temperature sealer to bedplates, foundations, and casings. Apply polysulfide sealant to faying surfaces. Use fasteners treated with ceramic coatings or use improved fasteners as applicable. Guidance item #1 applies to machinery foundations, bedplates, and fasteners.	Apply polyamide epoxy paint. Apply strippable coatings to fasteners.
2553	Pumps, Main Feed Booster, Emergency Feed, Feed Transfer	When main feed booster pumps are removed from the ship for overhaul or replacement, apply wire sprayed aluminum with low-temperature sealer to bedplates, foundations, and casings. Apply polysulfide sealant to faying surfaces. Use fasteners treated with ceramic coatings or use improved fasteners as applicable. Guidance item #1 applies to machinery foundations, bedplates, and fasteners.	Apply polyamide epoxy paint. Apply strippable coatings to fasteners.
2554	Main and Auxiliary Condensate Piping and Accessories	When steel valves, piping, pipe hangers, and sway braces are removed from the ship for overhaul or replacement, apply wire sprayed aluminum with heat-resisting high-temperature sealer. Use fasteners treated with ceramic coatings or use improved fasteners as applicable. Guidance item #3 applies to valves, and guidance item #2 applies to piping, hangers, and fasteners.	Apply polyamide epoxy paint. Apply strippable coatings to fasteners.
2556	SSTG Auxiliary Condensate Pumps	When auxiliary condensate pumps are removed from the ship for overhaul or replacement, apply wire sprayed aluminum with low-temperature sealer to foundations, bedplates, and casings. Apply polysulfide sealant to faying surfaces. Use fasteners treated with ceramic coatings or use improved fasteners as applicable. Guidance item #1 applies to machinery foundations, bedplates, and fasteners.	Apply polyamide epoxy paint. Apply strippable coatings to fasteners.
2562	Main Circulating Pumps	When main circulating pumps are overhauled or replaced, apply wire sprayed aluminum with low-temperature sealer to foundation, bedplate, and casing. Use fasteners treated with ceramic coatings or use improved fasteners as applicable.	Apply polyamide epoxy paint. Apply strippable coatings to fasteners.

Table F-2. CORROSION-CONTROL GUIDANCE ITEMS		
Item Number	Equipment	Guidance
1	Machinery Foundations and Bedplates	When a new foundation or bedplate is installed or a bedplate is removed as part of machinery overhaul, or a foundation is located topside, abrasive-blast the foundation and mating structure surface to white metal (SSPC-SP5), and then apply 7-10 mils of WSA low-temperature sealer (MIL-P-23377) and two-coat polyamide epoxy (MIL-P-24441) system. For machinery foundations and bedplates located in machinery spaces and subjected to temperatures above 175°F, use WSA with high-temperature sealer (DOD-P-24555). Use fasteners treated with ceramic coatings or use improved fasteners.
2	Piping and Hangers	In areas exposed to the weather and in machinery spaces (where piping is replaced) abrasive-blast ferrous piping and pipe hangers/brackets to white metal (SSPC-SP5) and apply 7-10 mils of WSA, low- or high-temperature sealer (depending on operating temperature), and polyamide epoxy coating (MIL-P-24441). If piping is not replaced, apply three-coat polyamide epoxy system (MIL-P-24441). Treat fasteners with ceramic coating (MIL-C-81751) or use CRES fasteners.
3	Valves	Abrasive-blast valve exterior to white metal (SSPC-SP5) and apply 7-10 mils of WSA, low- or high-temperature sealer (depending on operating temperature of fluid or if steam valve), and polyamide epoxy coating (MIL-P-24441). Technical Manual NAVSEA S6435-AE-MMA-010/W, *Sprayed CTT, External Preservation of Steam Valves Using Wire Sprayed Aluminum Coatings*, provides detailed guidance. Upgrade/treat fasteners with ceramic coating (MIL-C-81751) or replace with CRES fasteners and apply polysulfide sealant (MIL-S-81733).

APPENDIX G

SHIPALT SUMMARY

This appendix summarizes shipalts that have an impact on the reliability and maintainability of the main feed pumps.

SHIPALT NUMBER: LPH-496K

BRIEF: Installation of Main Feed Pump Overspeed Trip

1. PURPOSE: To enhance personnel safety and to improve reliability by installing an overspeed trip for the main feed pump turbines. Overspeed trip devices are not installed on the existing main feed pump turbines.

2. DESCRIPTION/PHYSICAL IMPACT: An overspeed trip system for the main feed pump turbines will be installed that will shut off all steam to the turbine governing (or nozzle control) valve, in order to fully stop the turbine in the event a predetermined speed is exceeded.

3. WORK REQUIREMENTS: Install an overspeed system for the main feed pump turbines. Install a remote overspeed alarm in the enclosed operating station. The overspeed trip system shall consist of the following: a speed sensing device with a magnetic proximity pickup and a relay medium - (a) mechanical, (b) hydraulic, (c) electrical/electronic; any one of those listed or a combination may be installed. The following material will be provided by NAVSHIPS: Overspeed Trip Kits; consisting of magnetic proximity pickups (3), solenoid dump valves (3), monitor panel with display of turbine RPMs, switches, indicating lights, alarms and power supply (1), and Tachometers, fixed 0-10,000 RPM (3). The enclosed operating station remote overspeed alarm will be provided by the installing activity. Plans of the overspeed trip shall be obtained from the vendor for each make of feed pump turbine. Modify Technical Manuals, Ship's Information Book and provide PMS feedback for update of Maintenance Requirement Cards to reflect this installation.

4. INTERRELATED ITEMS: None.

5. REFERENCES: None.

6. SUMMARY/MISCELLANEOUS COMMENTS: This SHIPALT is not applicable to LPH-12.

SHIPALT NUMBER: LPH-614K

BRIEF: Main Feed Pump Overspeed Trip System

1. PURPOSE: Not defined

2. DESCRIPTION/PHYSICAL IMPACT: Install a main feed pump (MFP) overspeed trip system.

3. WORK REQUIREMENTS:

   (a) Install a main feed pump (MFP) overspeed trip system as follows:

      (1) Install, for each MFP, the speed sensing magnetic pickup and it's associated electronic amplifier.

      (2) Install in the steam inlet line to each MFP, the new steam hydraulic trip valve. This valve shall be installed before the existing regulating valve of the MFP. Provide fittings necessary to adapt piping to valve provided.

      (3) Install necessary piping and fittings to connect the existing solenoid operated valve to the new hydraulic trip valve.

      (4) On the Terry Corporation BTBSCS turbines of the USS TRIPOLI (LPH-10) and USS NEW ORLEANS (LPH-11), install a new 60 tooth gear on the end of the turbine shaft. A cover plate or inspection door will be provided for mounting the new magnetic proximity pickup.

      On the Hardie-Tynes turbines of USS GUAM (LPH-9), a new 60 tooth sprocket shall be installed on the coupling and the magnetic pickup shall be mounted on a mounting bracket attached to the foundation of the MFP.

   (b) There are three MFPs installed on each ship. Applicable documentation is:

HULL	APL/CID	TECH MANUAL
USS GUAM (LPH-9)	017020022 Pump	0347-LP-401-0000
	057960014 Turbine	
USS TRIPOLI (LPH-10)	016020793 Pump	0347-4369
	057950103 Turbine	
USS NEW ORLEANS (LPH-11)	016020977 Pump	0347-4369
	057950143 Turbine	

SHIPALT NUMBER: LPH-614K

BRIEF: Main Feed Pump Overspeed Trip System

(c) The steam trip valve utilizes lube oil pressure via the solenoid operated valve to hold the hydraulic trip valve in the open (unit operating) position. In the event that unit speed exceeds prescribed limits, the monitor panel energizes the solenoid operated valve and lube oil pressure on the hydraulic trip valve is relieved by dumping lube oil to the sump. This action actuates the hydraulic trip valve securing the unit. The hydraulic trip valve is so designed that steam pressure assists in closing the valve. A manual lever is provided on the hydraulic trip valve to enable unit light-off.

4. INTERRELATED ITEMS:

5. REFERENCES:

6. SUMMARY - MISCELLANEOUS COMMENTS: This SHIPALT is applicable to LPH 9, 10 and 11 only.

SHIPALT NUMBER: LHA-169K

BRIEF: MFP Overspeed Trip System

1. PURPOSE: To improve personnel safety, reliability and reduce maintenance of the main feed pumps.

2. DESCRIPTION/PHYSICAL IMPACT: Provide overspeed protection, low lube oil sensor and a low suction pressure sensor for the main feed pumps. The following equipment shall be provided:

   (a) (4) Electronic Safety Shutdown Assembly - Consisting of:
   - (1) Monitor Panel
   - (2) Trip Solenoid Valve
   - (3) Magnetic Pickup (Speed Sensor)
   - (4) Fittings, Cable Connectors and Plugs

   (b) (4) Main feed pump steam trip valve

   The electronic monitor panel will be furnished in a splash proof enclosure and include power on/off switch, one green indicator light for normal operation, one red indicator light to show steam trip valve closed, an indicator light test push button, a system/solenoid test pushbutton, a light emitting diode digital display of shaft speed and will retain overspeed readout until reset, one indicating light for low lube oil, one indicating light for loss of suction, means for adjusting trip, time delay to permit light off, manual trip pushbutton and all electronics solid state.

3. WORK REQUIREMENTS: Remove existing main feed pump (MFP) overspeed trip system. Instal new MFP overspeed trip systems as follows:

   (a) Install the electronic monitor panel adjacent to MFP reference (a) and (b).
   (b) Install the magnetic pickup, reference (b).
   (c) Install adjacent to the electronic monitor panel an audible/visual alarm, reference (a).
   (d) Install in MFP steam inlet line the new steam trip valves,
   (e) Install new solenoid trip valve.
   (f) Install MFP low suction pressure trip system.
   (g) Install a lube oil pressure sensor.
   (h) Install electrical cabling.
   (i) Install lube oil piping.

4. INTERRELATED ITEMS: Not defined

5. REFERENCES : (a) SHIPALT Sketch
   (b) NAVSHIPS 0947-182-8010

6. SUMMARY - MISCELLANEOUS COMMENTS: None

SHIPALT NUMBER: LHA-170K

BRIEF: MFP Standard Lube Oil System

1. PURPOSE: To standardize lube oil system with commonality of parts for improved lube oil temperature control and oil filtration and automatic water removal capability.

2. DESCRIPTION/PHYSICAL IMPACT: Installation of new components and reconfiguration of existing MFP lube oil systems will provide a standard system configuration in addition to provision of auto start-up of auxiliary lube oil pumps on loss of oil pressure and adequate oil/capacity for all conditions of operation.

3. WORK REQUIREMENTS: Installation of Main Feed Pump Lube Oil Systems Modification Kit on each unit will consist of: Centrifugal separator, centrifilter thrust washer housing, thrust washer, lube oil filter, T.D. relay, pressure regulating valve, lube oil filter DP indicator and alarm switch, supply pressure switch, DP switch, centrifugal separator supply pressure regulator, centrifugal separator supply (1/2") and drain (1/4") solenoid valve and lube oil thermostat.

4. INTERRELATED ITEMS: None.

5. REFERENCES: None.

6. SUMMARY/MISCELLANEOUS COMMENTS: None.

LHA-170K
1 of 1

7/1/81
REVISED DATE

SHIPALT NUMBER: LPH-611D

BRIEF: Improve Main Feed Pump Governor Electronics

1. PURPOSE: Not defined

2. DESCRIPTION/PHYSICAL IMPACT: Not defined

3. WORK REQUIREMENTS: Not defined

4. INTERRELATED ITEMS: Not defined

5. REFERENCES: Not defined

6. SUMMARY - MISCELLANEOUS COMMENTS:

SHIPALT NUMBER: LPH-609D

BRIEF: Main Feed Pump Flexible Couplings

1. PURPOSE: To improve the reliability and maintainability of the Main Feed Pumps by replacing the existing flexible couplings with new non-lubricated flexible couplings.

2. DESCRIPTION/PHYSICAL IMPACT: Provides for new non-lubricating flexible couplings for the Main Feed Pumps. These couplings are capable of substaining a high degree of misalignment without failure (maximum 80 mils). The new coupling shall be bored to suit their particular installation.

   Material provided for the accomplishment of this SHIPALT is as follows:

   (3) Coupling, flexible, "REX" Coupling Division, Model 301DBZ-X or equivalent.

3. WORK REQUIREMENTS: Remove existing flexible couplings from Main Feed Pumps. Install new non-lubricating flexible couplings and align pumps to the turbine.

4. INTERRELATED ITEMS: None

5. REFERENCES: The references are equipment related as follows:

Hull	Turbine and Pump Tech. Manual
LPH-2,3 and 7	347-3646
LPH-9	0347-LP-401-0000
LPH-10 and 11	347-4369

6. SUMMARY - MISCELLANEOUS COMMENTS: LPH-12 does not require this SHIPALT. This SHIPALT is applicable to the LPH-2,3,7,9,10 and 11 only.

SHIPALT NUMBER: LPH-0527D

BRIEF: **Replace Main Feed Pump Recirculating Restrictor**

1. PURPOSE: To improve maintainability of main feed pump recirculating line.

2. DESCRIPTION/PHYSICAL IMPACT: The existing main feed pump recirculating line multiple orifice type by-pass reducers will be replaced with a new type flow restrictor designed to reduce flow velocity and line pressure with minimum fluid flashing across the restrictor.

3. WORK REQUIREMENTS: Remove the multiple orifice type by-pass pressure reducers from the main feed pump recirculating lines and install Main Feed Pump Self-Drag Restrictors provided by Ships Parts Control Center. All other material to be provided by the installing activity.

4. INTERRELATED ITEMS: None

5. REFERENCES: None

6. SUMMARY - MISCELLANEOUS COMMENTS: None

SHIPALT NUMBER: LPH-802K

BRIEF: Feed Pump Control System Modifications

1. PURPOSE: To standardize the Feed Pump Control (FPC) system configuration and components to improve system reliability, maintainability and performance.

2. DESCRIPTION/PHYSICAL IMPACT: Replace existing FPC system with a General Regulation FPC system.

3. WORK REQUIREMENTS: Not defined.

4. INTERRELATED ITEMS: None.

5. REFERENCES: None.

6. SUMMARY/MISCELLANEOUS COMMENTS: The work requirements for this SHIPALT are not defined at this time. This alteration is applicable to LPH-12 only.

SHIPALT NUMBER: LHA-262D

BRIEF: Main Feed Pump (MFP) Suction Pressure Gauge

1. PURPOSE: To provide a pressure gauge for monitoring the Main Feed Pump (MFP) suction pressure as required by the Maintenance Requirement Card - Testing the Low Suction Pressure Safety Trip and Emergency Trip Valve.

2. DESCRIPTION/PHYSICAL IMPACT: Install a pressure gauge with isolation valve in the existing pressure switch sensing line downstream of each MFP local operating station gauge board. The pressure gauge shall have a 4-1/2 inch dial and a pressure range of 0-100 PSI.

3. WORK REQUIREMENTS: See paragraph 2.

4. INTERRELATED ITEMS: None.

5. REFERENCES: None.

6. SUMMARY/MISCELLANEOUS COMMENTS: The intent of this SHIPALT is to be accomplished on LHA-4 and LHA-5 by Class Item 4103 within the SCN period.

APPENDIX H

SOURCES OF INFORMATION

The specific sources of information used in this analysis are as follows:

1. Generation IV MDS narrative and part data for the LHA-1 and LPH-2 Classes for the periods May 1976 through June 1981 and January 1971 through March 1981, respectively.

2. CASREPs for the LHA-1 Class for the period 1 January 1976 through 22 April 1981, and for the LPH-2 Class for the period 1 January 1978 through 22 April 1981.

3. Maintenance Index Pages (MIPs) and maintenance requirement cards (MRCs) for the LHA-1 Class and LPH-2 Class Feed and Condensate System.

4. (LHA-1) Plan for Maintenance, Feed and Condensate Systems.

5. DDEOC Class Maintenance Plan (CMP) Comparison (FF-1052, DDG-37, CG-16, and CG-26 Class Ships), Study for PERA (CRUDES) dated September 1980.

6. Results of ARINC Research Corporation visit to David Taylor Naval Research and Development Center, dated 12 May 1982.

7. Technical Manuals as listed (all NAVSHIPS):

   - 0202-LP-623-3000, *Index of Technical Manuals, USS IWO JIMA (LPH-2)*.
   - 0904-LP-108-1010, *Technical Manual Index for Amphibious Assault Ship, USS GUADALCANAL (LPH-7)*.
   - S9LPH-03-ITM-010/LPH-3, *Technical Manual Index, USS OKINAWA (LPH-3)*.
   - 0905-LP-496-1010, *Operating Guide for Propulsion Machinery, USS OKINAWA (LPH-3)*.
   - 0905-LP-502-5010, *Operating Guide for Propulsion Machinery, USS IWO JIMA (LPH-2)*.

- 0905-LP-620-2010, *Operating Guide for Propulsion and Auxiliary Systems, LHA-1 Class Ship,* Ingalls Shipbuilders, Pascagoula, Mississippi.
- 0905-LP-620-4100, *USS OKINAWA (PHA-3) Ship Information Book, Volume 1: Hull and Mechanical.*
- 347-4101, *Technical Manual, Main Feed Pumps,* Warren Pumps, Inc.
- 0947-132-6010, *Type 1 Technical Manual for Main Condensate Pump.*
- 0947-179-5010, *Type 1 Equipment Manual for Main Condenser Condensate Pump.*
- 0947-LP-136-6010, *Type 1 Equipment Manual for Emergency Feed Pump.*
- 0947-LP-131-8010, *Type 1 Technical Manual for Main Feed Pumps.*
- 0947-179-6010, *Type 1 Equipment Manual for Auxiliary Condensate Pump.*
- 347-3980, *Technical Manual for Main Condenser Condensate Pump.*
- 347-3660, *Technical Manual for Main Feed Booster Pump,* Warren Pumps, Inc.
- 0946-LP-018-2010, Equipment *Manual for Main Condenser.*
- 347-4010, *Technical Manual, Main Feed Pumps, Steam-Turbine Driven.*
- 0947-138-2010, *Equipment Manual for Turbine-Driven Main Feed Pump.*
- 0947-124-1010, *Type 1 Technical Manual for Motor-Driven Main Feed Booster Pumps.*
- 0947-071-4010, *Type 1 Equipment Manual for Main Condenser Condensate Pump.*
- 0947-117-8010, *Type 1 Technical Manual for Main Feed Pumps and Turbines.*
- 0947-061-7010, *Type 1 Technical Manual for Motor-Driven Main Feed Booster Pumps.*
- 347-4369, *Technical Manual for Main Feed Pump,* Warren Pumps, Inc.

8. System Engineering Analyses (SEA) of Boiler Feed Pumps Installed on AFS-1, AOE-1, and AOR-1 Class Ships.

9. Ship Alteration and Repair Packages (SARPs)

   - LPH-2, dated 6/8/82
   - LPH-3, dated 3/11/82

- LPH-7, dated 10/31/80
- LPH-9, dated 8/18/80
- LPH-10, dated 1/9/81
- LPH-11, dated 10/23/81
- LPH-12, dated 5/15/81
- LPA-1, dated FY 78 RAV
- LHA-2, dated 6/13/83 (COH)
- LHA-1, dated FY 81 (COH)
- LHA-3, dated 1/15/82 SRA
- LHA-2, dated 7/3/81 SRA

10. Ship Alteration Information Manuals for LHA-1 and LPH-2 Class ships.

11. COMNAVSURFLANT and COMNAVSURFPAC Type Commanders' Coordinated Shipboard Allowance Lists (COSALs), dated July 1981 and June 1981, respectively.

12. COMNAVSURFLANTINST 9000.1, NAVSURFLANT Maintenance Manual, 12 June 1975, through change 5, dated 27 February 1978.

13. COMNAVSURFLANTINST 4700.1, *COMNAVSURFPAC Ship and Craft Material Maintenance Manual,* Volume I, 6 June 1975.

14. *FF-1052, Class Feed and Condensate System, Review of Experience,* SMA-102-255, October 1976, ARINC Research Publication 1645-03-1539.

15. *DDG-37 Class Feed and Condensate Systems, Review of Experience,* SMA-37-101-255, March 1978, ARINC Research Publication 1652-03-12-1732.

16. *CG-16 and CG-26 Class Main Propulsion Systems, Review of Experience,* SMA-1626-300, September 1979, ARINC Research Publication 1671-04-2-2051.

17. OPNAVINST 4790.4, *Material Maintenance Management (3-M) Manual,* Volumes I, II, and III, June 1973.

18. Common Configuration Class List (CCCL) for LHA-1 and LPH-2.

19. Ship Work Authorization Boundaries (SWABs), Surface Ships, March 1981.

20. Results of ARINC Research Corporation vistis to LPH-7 and LPH-12 on 20-21 April 1982.

21. Class Maintenance Plans (CMPs) for FF-1052 Class, DDG-37 Class, CG-16 and CG-26, and LHA-1 Class ships.

22. Results of ARINC Research Corporation visit to LHA-2 on 4 June 1982.